Essays in Systematic Asset Pricing

Dissertation
submitted to the
Faculty of Business, Economics and Informatics
of the University of Zurich

to obtain the degree of
Doktor der Wirtschaftswissenschaften, Dr. oec.
(corresponds to Doctor of Philosophy, PhD)

presented by

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The Faculty of Business, Economics and Informatics of the University of Zurich hereby authorizes the printing of this dissertation, without indicating an opinion of the views expressed in the work.

Zurich, 17^{th} July 2019

Chairman of the Doctoral Board: Prof. Dr. Steven Ongena

Acknowledgements

"Sometimes life hits you in the head with a brick. Don't lose faith. Stay hungry, stay foolish"

- Steve Jobs

I dedicate this dissertation to my family.

To start with, I would like to express my utmost gratitude to Dr. Alexandre Ziegler for his excellent mentoring over the years. I am grateful he taught me essential concepts in asset pricing and research. Then, I would like to thank Prof. Dr. Steven Ongena for his supervision, support and for giving me the time to invest in myself. Without them, this experience would not have been the same. Then, I would like to thank Prof. Dr. Felix Kübler and Prof. Dr. Norman Schürhoff for research feedback, support over the job market and for being part of my Ph.D. thesis committee. Further, I would also like to thank Prof. Dr. Michel Habib for his wisdom and thorough discussions about life.

Next, I would like to thank Sylvie Golay, Dr. Michael Markovich and Dr. Nikola Vasiljević for their support and guidance during my delightful experience at Credit Suisse.

Furthermore, I would like to express my gratitude to all the colleagues and friends that encouraged me over the years: Marlon Azinovic, Olga Briukhova, Stefan Bruder, Bruno Caprettini, Marco Ceccarelli, Kathrin DeGreiff, Gianluca De Nard, Ming Deng, Dietmar Dorn, Sebastian Dörr, Felix Fattinger, Fulvia Fringuellotti, Luca Gaegauf, Marco Gambacciani, Emilia Garcia, Thomas Geelen, Runjie Geng, Regina Hammerschmid, Lena Hörnlein, Alexandra Janssen, Gazi Kabas, Dominika Kryczka, Ferdinand Langnickel, Philipp Lentner, Mukhlynina Lilia, Egor Maslov, Luca Mazzone, Kevin Meyer, Mrinal Mishra, Kuchulain O'Flynn, Diego Ostinelli, Yushi Peng, Ivan Petzev, Stefano Ramelli, Thomas Richter, Jakub Rojćek, Lilia Ruslanova, Simon Scheidegger, Anastasiia Sokko, Felix Stang, Juliette Thibaud, Daniele Titotto, Bruno Troja, Nikola Vasiljević, Patrick Walker, Max Winkler, Jiri Woschitz and Hanlin Yang.

Last but not least, I am filled with gratitude towards Mirella, Umberto, Sandro and Martina for their limitless support and encouragement.

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Part I

Introduction

Chapter 1

Introduction and Summary of Research Results

Investing is about answering three questions regarding the valuation of assets. What to buy? What to sell? When to do it? To answer these questions, quantitative researchers seek systematic patterns in data. The systematic component of the analysis means to identify a persistent bias in a security or periodic event that will lead the security price in a specific direction. The predicted pattern will hold on average, but not always. Accordingly, the majority of systematic strategies are at most a statistical arbitrage, but not a pure arbitrage.

Each researcher has its own method to identify biases in securities. I find derivative instruments to have a common feature. They are rule based by construction. Accordingly, I find them a solid ground to explore systematic strategies.

This doctoral dissertation entitled *"Essays in Systematic Asset Pricing"* explores the above questions in derivative markets. It consists of three papers investigating empirically the systematic movement of option and leveraged exchange traded product returns.

"International Volatility Arbitrage" is the first paper and presented in chapter 2. This paper studies option returns globally. Are options on exchange-traded products (ETPs) and indexes consistently priced internationally? The cross-section of international option returns exhibits a mispricing by sorting on ex-ante volatility returns. In addition, selling international ETP options and buying their corresponding index options commands a positive risk premium. Both empirical findings are economically large and pervasive internationally, whereas they are comparably small domestically. While volatility hedge funds are exposed towards domestic option products, they neglect the possibility of engaging in foreign volatility arbitrage. These findings entail that alpha seekers may expand their horizon towards international derivatives which at first glance are similar, but institutionally are not.

"The Timing of Option Returns" is the second paper, written jointly with Dr. Alexandre Ziegler, and presented in chapter 3. This paper investigates when to short options. The returns from shorting out-of-the-money S&P 500 put options are concentrated in the few days preceding their expiration. Back-month options generate almost no returns, and front-month options do so only towards the end of the option cycle. The concentration of the option premium at the end of the cycle reflects changes in options' risk characteristics. Specifically, options' convexity risk increases sharply close to maturity, making them more sensitive to jumps in the underlying price. By contrast, volatility risk plays a

smaller role close to maturity. Our results imply that portfolio managers wishing to harvest the put option premium should short front-month options only during the last days of the cycle, while investors wishing to protect against downside risk should use back-month options to reduce hedging costs.

"Leveraged ETPs Across Asset Classes" is the third paper and presented in chapter 4. This paper studies the pricing discrepancy between leveraged exchange traded products (LETPs) and underlying exchange traded products (ETPs). Specifically, LETPs exhibit different monthly returns than their underlying geared ETPs. The effect is known as LETP slippage. The research project investigates LETP slippage across five asset classes: equity developed, equity emerging, commodity, fixed income and currency markets. High volatility asset classes show larger slippage than low volatility asset classes. In the cross-section, LETP slippage is more pronounced in instruments with high return variability. A portfolio of liquid and volatile LETPs yields risk-adjusted returns of 12.50% on an annual basis. Further, LETP slippage is either zero or negatively correlated with the same asset class ETP market portfolio. Accordingly, LETP slippage can be used as a diversification instrument when combined with a broad market index.

The main conclusions of this dissertation are the following. First, attractive returns could reside between securities that at first glance are similar, but institutionally are not. Second, reading derivative contracts provides intuition about their systematic behavior. Third, exploring newly-issued derivatives could be an interesting path for unexplored returns.

Part II

Research Papers

Chapter 2

International Volatility Arbitrage

Adriano Tosi[1]

Abstract

Are options on exchange-traded products (ETPs) and indexes consistently priced internationally? The cross-section of international option returns exhibits a mispricing by sorting on ex-ante volatility returns. In addition, selling international ETP options and buying their corresponding index options commands a positive risk premium. Both empirical findings are economically large and pervasive internationally, whereas they are comparably small domestically. While volatility hedge funds are exposed towards domestic option products, they neglect the possibility of engaging in foreign volatility arbitrage. These findings entail that alpha seekers may expand their horizon towards international derivatives which at first glance are similar, but institutionally are not.

Keywords: Systematic Volatility Arbitrage, Cross-Section of Option Returns, Dispersion Trading

JEL Classification: G11, G12, G13, G14

[1]I would like to thank Alexandre Ziegler for his thorough comments. I also thank Marlon Azinovic, Stefan Bruder, Bruno Caprettini, Pierre Collin-Dufresne, Gianluca De Nard, Felix Fattinger, Damir Filipović, Laurent Frésard, Emilia Garcia, Runjie Geng, Amit Goyal, Michel Habib, Nir Jaimovich, Gazi Kabas, Felix Kübler, Markus Leippold, Egor Maslov, Luca Mazzone, Kuchulain O'Flynn, Steven Ongena, Ralph Ossa, Olivier Scaillet, Simon Scheidegger, Norman Schürhoff, and seminar participants at OptionMetrics Research Conference 2018, SFI Academic Job Market Workshop 2018, University of Zurich Brown Bag Lunch Seminar 2018 and University of Zurich Macroeconomics Doctoral Seminar 2018 for helpful comments.

2.1 Introduction

Most empirical option pricing research focuses on US option markets.[2] Nevertheless, little is known about option returns internationally. The increasing range of newly issued exchange-traded product (ETP) and index options worldwide raises two empirical questions. Are options consistently priced internationally? Do analogous US options exhibit similar pricing behavior?

This paper studies option returns in international and domestic-US markets. International options refer to equity options on country ETPs and indexes. For instance, I ask whether Korean ETP and index options are consistently priced with Brazilian derivatives. Domestic options refer to equity options on US ETPs and indexes. For example, I ask if ETP and index options on NASDAQ and S&P500 are consistently priced. This study shows two main empirical results among international derivative products. The first result is a cross-sectional mispricing. The second result is a dispersion trading risk premium. Both results are comparably small in the domestic derivative space. The sample period is 2006-2015.

First, I consider an analysis *across* financial instruments by pooling together all the country ETP and index options. Specifically, the cross-section of international option returns on ETPs and indexes exhibits a mispricing by sorting on the relative valuation of implied and realized volatility (henceforth, ex-ante volatility returns). I construct ex-ante volatility returns as one minus the ratio of previous year realized volatility to time t implied volatility. Substantial volatility deviations across ETP and index options reveal an inconsistency in pricing of derivatives at the international level.

Second, I consider an analysis *between* financial instruments by taking the difference between ETP and index option returns on the same country. Explicitly, selling international ETP options and buying their corresponding country index options commands a positive risk premium. This dispersion premium is especially pronounced among options with high ex-ante volatility return difference. The pricing gap between ETP and index options depicts the presence of a premium which is not hedgeable by means of index options.

Both stylized facts are economically sizable internationally, with annualized risk-adjusted returns reaching 20%. The main determinants of the different pricing behavior of international options reside in volatility and institutional differences. These options have substantial heterogeneity in volatility and some contract specification discrepancies. The latter feature refers to option contracts, which may differ in expiration day, underlying asset, exercise-settlement and venue. In addition, international ETP products are recently issued. In this paper, I show that combining assets in different ways leads to capture diverse risk / return profiles. Specifically, these asset combinations tilt a strategy exposure towards either a mispricing (cross-section) or a risk premium (dispersion trading). To the best of my knowledge, this is the first paper that presents these findings. I report a literature review in Section 2.2.

The methodology adopted to study the systematic behavior of international option returns in the

[2] For instance, seminal papers of Coval and Shumway (2001), Goyal and Saretto (2009) and Driessen et al. (2009).

cross-section is a simple univariate sort. Each month, international at-the-money (ATM) straddles are sorted by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. Then, a long-short portfolio sells the expensive tercile, buys the cheap tercile and holds options to maturity. Domestic long-short portfolios are constructed similarly. After that, I analyze return and risk characteristics of these option strategies.[3]

International long-short option portfolios outperform the equivalent domestic option strategies, as shown in Figure 2.1. This figure shows cumulative returns of international and domestic option portfolios sorted by volatility returns. International long-short option strategies yield annualized average return (Sharpe ratio) ranging between 16.38% and 18.52% (1.83 and 2.29). These returns are neither spanned by equity nor volatility factor models, yielding risk-adjusted returns of similar magnitude as the raw returns. Despite their sizable abnormal returns, international long-short option returns are positively skewed and have a neutral exposure to the equity market. In contrast, domestic long-short option portfolios exhibit a weaker pattern in the data yielding annualized average return (Sharpe ratio) between 3.64% and 5.04% (0.56 and 0.67), as Table 2.1 shows.

By means of cross-sectional regressions, I show that volatility returns are an important determinant of the cross-sectional variation of option returns. Their significance is both statistically and economically more pronounced internationally than domestically. This predominance holds with and without controls. In line with this evidence, the paper analyzes the over-reaction of implied over realized volatility, by means of ex-post volatility returns.[4] The results show an unjustified cross-sectional variation of ex-post volatility returns across international options. Specifically, international long-short portfolios have average ex-post volatility returns ranging between 14.39% and 29.11% on a yearly basis. A smaller cross-sectional variation is present among domestic ex-post volatility returns, which range only between 7.25% and 19.33%.

I then investigate pricing differences between ETP and index options by selling country ETP straddles and buying the corresponding country index straddles. Each month, international ETP and index dispersion pairs are ranked by previous day volatility returns difference. Then, these pairs are assigned to one of three equally weighted tercile portfolios and held to maturity. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. Domestic high dispersion trading portfolios are constructed similarly, by pairing domestic ETP and index straddles. Then, I examine the distribution characteristics of these ETP-index spread portfolio returns.

The dispersion risk premium is concentrated among international option products rather than in the domestic derivative space, as shown in Figure 2.2. This figure depicts cumulative returns of international and domestic high dispersion trading portfolios in which the former are considerably higher than the latter. Concretely, international high dispersion trading portfolios generate annualized average

[3]Throughout the paper, all option returns are excess returns, denominated in US dollars and computed at mid-price, unless it is stated differently.

[4]I construct ex-post volatility returns as one minus the ratio of ex-post realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t + \tau$.

returns between 24.97% and 26.23%. Consistently, their annualized Sharpe ratio is substantial, ranging from 2.03 to 2.25. Not surprisingly, standard equity and volatility factor models cannot explain these returns. Different results are shown by the domestic high dispersion trading portfolios which yield a lower annualized average return ranging between 1.48% and 1.98%. To such a degree, the domestic Sharpe ratio is minimal, varying between 0.14 and 0.19, as Table 2.1 reports. Even though international high dispersion trading portfolios have low market exposure, they are exposed to higher moment risks. Specifically, international high dispersion trading standard deviation is larger than the domestic equivalent volatility risk, with a relative difference up to 90%. Similarly, international high dispersion trading returns are negatively skewed, implying the possibility of steep drawdowns.

The discrepancy in pricing between ETP and index options internationally is further supported by the gap in volatility returns between these two instruments. In particular, a one-standard-deviation increase in the wedge between ETP and index volatility returns implies an increase of 136 basis points in next month dispersion trading option returns. In contrast, domestic derivatives do not show such a pronounced elasticity. Consistent with this finding, the same country options on different underlying assets can exhibit remarkably different ex-post volatility returns. Their difference can be up to 34.70% on an annual basis. With smaller dispersion, the equivalent domestic ex-post volatility returns vary only between 2.96% and 10.98%. The presence of a risk premium between international derivatives is further corroborated by the low correlation of their underlying assets. This attenuated comovement can be attributed to institutional differences, e.g. diverse market capitalization. Therefore, international ETP and index options may react differently to exogenous shocks. As a result, a premium should be priced between these contingent claims to compensate for heterogeneous product specifications.

To further inspect the main source of these substantial option returns, I analyze the cross-sections of ETP and index options separately, both in international and domestic markets. The key finding is that the volatility mispricing is concentrated in international ETP options.

While the exposure of hedge funds towards volatility products is a known fact, I document that volatility hedge funds are not exploiting volatility deviations among international option products. By means of univariate regressions of hedge funds indexes on international and domestic option strategies, I find a statistical significant exposure of these funds only towards domestic option portfolios. These simple regressions may imply the possibility of finding some opportunities in foreign volatility arbitrage.

The main implications of this study are the following. First, good returns may reside between securities that at first glance are similar, but institutionally are not. Second, exploring newly-issued exotic contingent claims may be an interesting path for unknown returns. Third, hedge funds seeking for alpha may expand their horizon towards international derivative products.

The paper is organized as follows: Section 2.2 provides a literature review, Section 2.3 describes the data, Section 2.4 explains the methodology, Section 2.5 presents the empirical results and Section 2.6 concludes.

2.2 Literature Review

This paper contributes to four different strands of literature. The first one is the growing literature on international options, the second studies domestic-US index options, the third investigates the cross-section of option returns, and the fourth analyzes dispersion trading strategies.

This study is related to the literature exploring the systematic behavior of international options. In particular, Hodges et al. (2003) find that out-of-the-money (OTM) call and put options on S&P 500 and FTSE 100 index futures yield large negative returns for the period 1985-2002. Driessen and Maenhout (2013) study international index option returns on S&P 500, FTSE 100 and Nikkei 225 for the period 1992-2001. They show that volatility and jump risk factors are priced in foreign option products. In addition, they find that UK and US derivatives are increasingly interdependent. Kelly et al. (2016) study the price of political uncertainty across 20 countries for the period 2002-2012. They find that options' implied volatility and variance risk premium are higher for those countries facing political elections, implying that options provide protection for tail risk. Andersen et al. (2019) find a priced left tail risk factor in equity index options among six European indexes. They show a differential risk factor among countries during the European sovereign debt crises. Israelov et al. (2017) document the profitability of covered call writing across eleven global indexes, for the period 2002-2015.

My paper complements this literature by studying the return and risk characteristics of option strategies across 28 countries and 46 different international option products. I show that there is a large cross-sectional variation in straddle returns across international ETP and index options by sorting on ex-ante volatility returns. Furthermore, this international long-short option portfolios cannot be explained by standard risk factors and hedge funds strategies.

This paper is linked to the research investigating domestic-US index option returns. The literature finds that straddles and OTM put options yield large and puzzling returns. In particular, S&P 100 and S&P 500 straddles have been documented to yield weekly returns of -3% (Coval and Shumway (2001)). Similarly, S&P 500 options generate monthly returns of -50% (Santa-Clara and Saretto (2009)) and they are unexplained by common risk factors (Jackwerth (2000)). Consistent negative variance risk premium is shared by S&P 500 futures options (Bakshi and Kapadia (2003), Broadie et al. (2009), Bondarenko (2014) and Ziegler and Ziemba (2015)). Other studies show that index option returns are larger in non-trading periods (Jones and Shemesh (2018) and Muravyev and Ni (2016)). These enormous index option returns have been rationalized by potential mispricing explanations (Constantinides et al. (2009) and Faias and Santa-Clara (2017)) and consistency or inconsistency of these returns with option pricing models (Broadie et al. (2009) and Jones (2006)). Others explain the index options' expensiveness by the demand of market participants (Bollen and Whaley (2004) and Garleanu et al. (2009)). Closely related to this paper, Ammann and Herriger (2002) investigate volatility arbitrage strategies across S&P 500, S&P 100 and NYSE composite index options for the period 1995-2000. They find that there are some volatility deviations which can be profitably exploited. Koijen et al. (2017) extend the concept of FX carry trade to six different asset classes, among which ten US index options for the period 1996-2011. They find that index option carry-trade portfolios yield substantial risk-adjusted returns, but with negative skewness, by sorting on the option term structure slope. Lastly, Agarwal and Naik (2004) and Agarwal et al. (2017) show the exposure of hedge funds towards S&P 500 index OTM put options, straddles and VIX related strategies.

The paper contributes to this literature by analyzing the return and risk characteristics of 52 different derivative products among ETP and index options in the domestic US market. I document a moderate profitability of domestic long-short option portfolios sorted by ex-ante volatility returns. Finally, I document that volatility hedge funds are exposed towards domestic ETP and index options, while neglecting the possibility of using international volatility spread strategies.

The paper is associated to the literature on the cross-section of US equity stock option returns which finds an extensive set of potentially profitable sorts. Specifically, sorts on historical-implied volatility difference (Goyal and Saretto (2009)), call-put implied volatility difference (Doran et al. (2013)), idiosyncratic volatility (Cao and Han (2013b)) underlying volatility (Hu and Jacobs (2017)), ex-ante skewness (Boyer and Vorkink (2014)), term-structure slope (Jones and Wang (2012), Vasquez (2017), Campasano and Linn (2016)) and moneyness (Ni (2008)). Schürhoff and Ziegler (2011) rationalize some of the volatility findings by showing that common idiosyncratic variance risk is an essential determinant of the cross-section of stock option returns. Additionally, Goodman et al. (2018) document how accounting information adds predicting power with respect to future option returns beyond implied and realized volatility. Cao et al. (2017) forecast the cross-section of option returns by means of past stock returns, firm profitability, cash holding, new share issuance and analyst's dispersion.

Consistent with the previous literature, this paper finds that the relative valuation of implied to realized volatility is a strong predictor of future option returns. I complement this literature by showing that the international cross-section of ETP and index option returns is mispriced by sorting on ex-ante volatility returns. Furthermore, I show that this mispricing is especially pronounced across international ETP options.

My paper is closely related to the literature studying dispersion trading strategies. The existing literature document the different behavior between US index options and US equity stock options. Specifically, Carr and Wu (2009) find a negative variance risk premium in index options and approximately zero among 35 equity stock options. Driessen et al. (2009) explain dispersion trading strategies between S&P 100 index options and constituent equity stock options with a correlation risk argument. Schürhoff and Ziegler (2011) show that the correlation risk premium is a combination of systematic and idiosyncratic volatility risk premia. Successively, Driessen et al. (2013) show a large gap between implied and realized correlation on S&P 500 and Dow Jones 30 indexes and constituent options, confirming the presence of a pervasive risk premium. Buraschi et al. (2014b) find that analyst's forecast dispersion is positively associated with the difference of index and single stock options volatility risk premia. By means of correlation swap products on S&P500 stocks, Buraschi et al. (2014a) document that the cross-section of hedge funds returns is exposed towards dispersion trading strategies. A recent paper investigates the volatility gap between index and single stock options at the international level. Faria et al. (2018) analyze the correlation premium between CAC40, DAX, EuroStoxx50, FTSE100, SMI and SPX index options and constituent single stock options for the period 2002-2012. They find a statistically significant and economically positive correlation premium in international markets.

So far, the literature has studied the volatility gap between index and single stock options. My research differs from the previous one by studying the relative valuation between ETP and index options. I complement the literature by showing that international ETP options command a positive dispersion trading risk premium with respect to the corresponding index options. The pricing gap between international ETP and index options is determined by large volatility deviations, contract specifications heterogeneity and newer issuance of the former instruments over the latter ones. This effect is only marginally shared by domestic ETP-index option products.

2.3 Data

This section presents the data used in the empirical analysis. The sample period is from January 2006 until the end of December 2015. Subsection 2.3.1 introduces international option data. Subsection 2.3.2 presents domestic option data. Subsection 2.3.3 considers institutional data. Subsection 2.3.4 lists factor models.

2.3.1 International Option Data

International option data has daily frequency and comes from OptionMetrics IvyDB database. Within the MSCI world universe, I select one ETP and one index option product for each country available in the database. The data is collected as of August 2017. Table 2.7.1 shows international ETP and index option specific market, financial product, start and end year of the sample. A list of option variables is reported in Appendix 2.7.1. The international sample covers 28 countries. This data comprises 46 different equity option products among ETP options and index options.[5]

The international index option data covers 17 distinct countries. The international ETP option data consists of 27 countries and two instruments on world regions. The two world regions are on developed and emerging markets. These two instruments are among the first international ETP options issued in 2006. While there is a clear motivation for including these two instruments, their exclusion does not alter the result of this paper.

Over the entire sample period, there are 16 dispersion pairs of international ETP and index options. The countries for which I could merge ETP and index option products are all those among the international index option sample except Finland, which does not have ETP options traded. Panel (A) of Table 2.7.3 shows the paired financial products.

The international option sample spans over the 2006-2015 period due to data availability. International ETP options data is available since 2006. International index options recording data quality improved remarkably since mid 2000, both for pricing and contractual data. Appendix 2.7.3 outlines information about international index options data limitations before 2006.

2.3.2 Domestic Option Data

The domestic option sample is used as a comparison group. The option data has daily frequency and comes from OptionMetrics IvyDB database for the period 2006-2015. This sample is restricted as the international one for comparison on an uniform time range. Domestic ETP and index option products

[5] Option product specification rules are written for general ETP products as of 2017-08-31. The general definition of ETP products includes exchange-traded funds (ETFs), exchange-traded vehicles (ETVs) and exchange-traded notes (ETNs).

are selected as follows. First, I look for the universe of US equity cash indexes among three major exchanges widely used in the literature: NYSE, Nasdaq and NYSE American. Second, I then find ETP and index options available in the database which correspond to US equity cash index space. Table 2.7.2 shows domestic ETP and index option products, start and end year of the sample. The sample consists of 52 different domestic equity option products on ETP and index underlying assets.

The domestic index option sample consists of 16 products. The domestic ETP option sample covers 36 different instruments, among which 27 ETP options are on corresponding US equity cash indexes and nine on sector ETPs. The nine sector ETP options correspond to S&P 500 (SPX) sector space.[6] The sector ETP options inclusion aims to enlarge the number of pairs in the domestic dispersion trading analysis. Without the sector ETP options, the domestic dispersion trading number of ETP-index pairs would be approximately half of the corresponding international sample. While there is a clear motivation for including these sector products, their exclusion does not alter the conclusions of this paper.

Throughout the entire sample, I establish 19 pairs of domestic ETP and index options. ETP and index options referring to the same underlying broad cash index are matched, e.g. SPY with SPX options. While each sector ETP option is paired with SPX options. Panel (B) of Table 2.7.3 shows the paired derivative products at the domestic level. To conclude, Table 2.7.4 provides a summary overview of the entire option sample.

2.3.3 Institutional Data

Contractual and institutional data are from exchanges' websites, clearing houses and market makers worldwide.[7] These contract specifications cover expiration month / date, exercise-settlement value, AM / PM settlement, option multiplier and exercise style. A list of the exchanges' websites is in Appendix 2.7.2. Whenever possible, the first source of institutional information is the one provided by the exchanges. If needed, I complement this contractual information with the one provided by OptionMetrics database information files and Bloomberg data. In addition, changes in option contract specifications are taken into account over the 2006-2015 period. To mention a few examples: KOSPI 200 index options undertook a change in contract multiplier in March 2012, S&P 500-Mini options contract specifications changed from AM to PM settlement in November 2013 and London Stock Exchange LIFFE option contracts migrated to ICE Futures Europe in September 2014.

This paper considers only monthly options with the shortest maturity. Monthly options have a longer history, higher liquidity and are the most studied in the literature on SPX options. However, option products may have, at least, two near-term months and one month from a January, February or March quarterly cycle. Depending on the popularity of the derivative, options can have: long term equity anticipation security (LEAPS), quarterly, monthly, weekly or even daily options. For instance, Dutch index options have also daily expiration cycle. In addition, options with non-standard settlement for which additional securities or cash may be required at expiration are excluded.

To compute option returns, I take into account the heterogeneity in expiration day across different

[6]The only sector that does not have ETP traded options is real estate, which accounts for a mere 3% of SPX market capitalization.

[7]I would like to especially thank the following institutions for clarifications on option products specifications and for providing institutional data: Korean Exchange (KRX), KRX clearing house, Taiwan Futures Exchange, MEFF Exchange's market makers and services, BME Market Data, Borsa Italiana, ICE Exchange, London Stock Exchange and OptionMetrics.

option products worldwide. All option instruments considered in this paper have expiration date on the third Friday of the month, with the exception of five international index options. Specifically, Korean and Japanese index options usually expire on the second Thursday and Friday of the month, respectively. Similarly, Taiwanese and Australian index options usually expire on the third Wednesday and Thursday of the month, respectively. Finally, Hong Kong index options usually expire on the day preceding the last business day of the month.

All ETP options have PM settlement, whereas index options have either AM or PM settlement. Differences in AM and PM settlement among option products are taken into account while computing option returns.

In this study, all ETP options have physical delivery, whereas all index options are cash settled. At expiration, most of index options are settled with a special exercise-settlement value calculated by the exchange or the clearing house. Interestingly, calculations of the special exercise-settlement value can differ substantially across exchanges. For instance, some of the exchanges compute the special exercise-settlement value by employing the opening price of each constituent security in the index on the expiration date, e.g. SPX options. Others compute it as an average of the cash index over a predefined time interval before expiration, e.g. Taiwanese index options.

In this paper, ETP options have ETPs as underlying, while index options have as underlying security a cash index with only one exception. The exception is the Spanish IBEX-35 index options which are on front-month futures. I collect underlying prices and returns in local currency from OptionMetrics database, security and futures price files, and Bloomberg. Underlying asset returns are dividend and split adjusted. Option contracts multipliers denominated in local currency are collected from the exchanges websites.

ETP options have American exercise style. All international index options are European. Domestic index options can be either European or American depending on the particular contract specification. In this study, I neglect the early exercise of American options to facilitate computations.[8] Even though the early exercise assumption is widely used in the literature, I tested that this is not a concern for the option strategies presented in this paper. In particular, I find that the monthly option returns are of similar magnitude both in dividend and non-dividend months. In fact, American options are more likely to be exercised in presence of dividend payments. About 65% of the ETP products have dividend payments on March quarterly cycle and the remaining 35% on a semiannual and annual frequency in June and December. When excluding March, June, September and December from the entire analysis, I find that the remaining monthly returns have similar economic magnitude and statistical significance to those presented below.

[8]This early exercise assumption of American options is previously used in other academic studies in option strategies, e.g. Goyal and Saretto (2009), Driessen et al. (2009), Doran et al. (2013), Buraschi et al. (2014b), Boyer and Vorkink (2014) and Cao et al. (2017). Furthermore, Santa-Clara and Saretto (2009) show that the economic magnitude of S&P500 European and American option returns is similar. Consistently, Driessen et al. (2009) show that the early exercise premium of American index options is negligible for short-term options with days to maturity between 14 and 60. Evidence regarding the early exercise of American options in the academic literature is not conclusive. Researchers found that American options are both exercised more and less frequently than expected. For instance, Barraclough and Whaley (2012) find that a fraction of put equity stock options that should have been exercised early remain unexercised for the period 1996-2008. In contrast, Poteshman and Serbin (2003) find an irrational early exercise of American options among retail investors for the period 1996-1999 and Jensen and Pedersen (2016) show the possibility of an optimal early exercise due to funding costs.

2.3.4 Factor Return Data

I consider two equity and two volatility factor models to compute risk-adjusted returns and factors exposure of the option strategies considered throughout the paper. These factor models are widely used in the literature and among practitioners to evaluate hedge fund strategies. All the factors are excess returns expressed in US dollars.

The first equity factor model is a six-factor model comprised of Fama and French (2015) five-factor model in addition to Carhart (1997) momentum factor (henceforth domestic equity factor model). These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). The second equity factor model is a six-factor model comprised of Fama-French global five-factor and global momentum factor (henceforth international equity factor model). These global factors are constructed using stocks data from 23 countries worldwide and built with the same methodology as the domestic equity factor model. I take both the equity factor models monthly and daily data and US risk-free rate from Kenneth French's website for the period 2006-2015.[9]

The first volatility factor is a hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products (henceforth SV factor). The second volatility factor is a hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products (henceforth RV factor). Both of the monthly volatility factors come from Bloomberg for the period 2006-2015.[10]

I run univariate capital-asset-pricing-model (CAPM) regressions to investigate the systematic market-risk exposure of international and domestic option strategies. CRSP value-weighted index and MSCI world index monthly and daily data come from Kenneth French's website and Bloomberg, respectively, for the period 2006-2015.

In this paper, I run monthly time series regressions by matching the holding period of the equity factors as the one of the option portfolios. International options do not expire all at the same time. Hence, there is no unique holing period. I choose to approximate the holding period from the moment of portfolio formation to the third Friday of the month. The majority of international and domestic options expire on the third Friday of the month. Hence, this approximation is reasonable. However, my results are robust to different holding period of the equity factors. Section 2.5.7 reports robustness of the different possible regression specifications.

Lastly, spot foreign exchange rates (FX) data is from WRDS, Federal Reserve Bank monthly and daily FX spot files for the period 2006-2015. The obtained FX rates are in currency units per US dollar and used to convert foreign currency returns in US dollars.

2.4 Methodology

This section presents the volatility measures used in the relative valuation of securities, how option portfolios are built and option returns computed. The paper focuses on cross-sectional long-short and dispersion trading option strategies. The former type of option strategies exploits volatility deviations across straddles. The latter type of strategy exploits volatility deviations between ETP and index

[9] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[10] For further information on SV and RV factors see, CBOE website http://www.cboe.com/products/strategy-benchmark-indexes.

options pairs. Accordingly, I form two types of volatility measures to analyze securities across and between option instruments.

2.4.1 Volatility Measures

To asses the relative expensiveness of option products in the cross-section, I use ex-ante volatility returns, IV_t^r. They are estimated as one minus the ratio of previous year realized volatility to time t implied volatility, that is,

$$IV_t^r = 1 - \frac{RV_{t-12,t}}{IV_t}, \tag{2.1}$$

where $RV_{t-12,t}$ is the realized volatility estimated from the underlying returns daily data over the last 12 months. IV_t is the average implied volatility of ATM call and ATM put options at time t. The implied volatility is estimated using either Black and Scholes (1973), Cox et al. (1979) or Black (1976) model depending on whether the option contract is European, American or an option on futures, respectively. However, my results are robust to heuristically computing IV by Black and Scholes (1973) for all option types.

In addition, I use a model-free version of equation (2.1). Volatility returns are estimated by means of model-free volatility swap rate (VSR). VSR is computed by VIX index methodology for short term options.[11] In case of an insufficient number of strikes (lower than three) VSR is estimated by using the volatility approximation of Brenner and Subrahmanyan (1988). The VSR returns, VSR_t^r, are obtained by substituting IV_t with VSR_t in equation (2.1).

To assess the subsequent valuation of option portfolios in volatility terms, I estimate ex-post volatility returns. This volatility return is computed as one minus the ratio of ex-post realized volatility to time t implied volatility. I calculate the underlying ex-post realized volatility from time t to the option expiration day $t+\tau$ with daily returns data, $RV_{t,t+\tau}$. Then, the ex-post volatility returns are obtained by substituting $RV_{t-12,t}$ with $RV_{t,t+\tau}$ in equation (2.1). Its model free version uses VSR in place of IV.

I employ dispersion trading ex-ante volatility return to assess the relative expensiveness between ETP and index option pairs. I compute dispersion trading volatility return as the difference between ETP and index volatility return, formally given by

$$IV_{t,\text{ Dispersion}}^r = IV_{t,\text{ETP}}^r - IV_{t,\text{Index}}^r, \tag{2.2}$$

where $IV_{t,\text{ETP}}^r$ is the volatility return of an ETP option product and $IV_{t,\text{Index}}^r$ is the volatility return of the corresponding index product. Model-free versions as well as ex-post volatility returns follow accordingly by substituting the corresponding quantities in equation (2.2).

2.4.2 Option Portfolios

Portfolios are built without any look-ahead bias. To avoid any non-synchronous trading concern across time zones, I lag the entire information set used to construct portfolios by one day. In addition, cash

[11] https://www.cboe.com/micro/vix/vixwhite.pdf

flows are synchronized across products. This synchronization ensures that all instruments held in the portfolios have expired by the time the new option baskets are established. I choose to execute trades on the fourth Friday of each month. This day ensures to have Taiwanese and Australian cash flows always available, independently of the first day of the current and subsequent month. Results are robust to the choice of a different calendar time.

First, volatility measures and option returns are computed using the mid-price calculated from closing bid and ask prices. For international options, whenever the bid and ask prices are not available, I use the closing trade price or the settlement price published by the exchange. Second, I utilize only strike prices available at the moment of portfolio construction. Additional strike prices are usually issued when market participants make a specific request or the underlying passes the highest or lowest listed strike. Third, I ensure that option prices fulfill no-arbitrage conditions across strikes within each instrument, both at portfolio construction and at trade execution. Specifically for any strike $K_{i+1} > K_i$, I ensure that call prices satisfy $C(K_{i+1}) \leq C(K_i)$ and put prices satisfy $P(K_{i+1}) \geq P(K_i)$. In case of a no-arbitrage violation that specific option is excluded from the computations.[12] Fourth, options are selected with the level of the underlying. ATM options are those with the first strike price OTM. In order to build a straddle position, I require to have at least an ATM call and an ATM put. At the moment of trade execution, I select the previous day ATM call and put options.

The following portfolio construction is adopted for international and domestic options cross-sections, as well as at the micro level for ETP and index derivative cross-sections. Each month, straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). After that, options are held to maturity. I use both types of volatility returns for sorting, IV or VSR returns. The unconditional (U) portfolio return is the equally weighted average of all the straddles available at the moment of portfolio formation.

International and domestic dispersion trading portfolios are constructed in the following way. Each month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference, equation (2.2). Then, they are assigned to one of three equally weighted tercile portfolios. After that, I sell ETP straddles and buy the corresponding index straddles. Options are held to maturity. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs. A list of variables and measures aggregated in each portfolio is reported in Appendix 2.7.1.

I generalize the cross-sectional and dispersion trading analysis for international and domestic option portfolios by studying their time series properties. The portfolio construction is kept as previously described. However, I change the moment in which is executed. Specifically, option portfolios are

[12] Results are robust to the easing of the no-arbitrage screen. The largest violations of no-arbitrage, which is a recording error, belongs to CAC 40 index options for date 2010-04-20 and expiration contract 2010-05-21. The violation of no-arbitrage is confirmed by the data provider as of 2017-11-06.

constructed and trades are executed on the $n^{th}-1$ and n^{th} day since the last third Friday of the month. Cash flows are synchronized for each independent n^{th} day. The aim of this analysis is to show the pervasiveness and robustness of the pattern in the data documented in this paper. In addition, such an analysis shows heterogeneity in return and risk characteristics of different option strategies over time.

2.4.3 Option Returns

This subsection reports straddles and dispersion returns calculation. The long straddle return denominated in US dollar (USD) from time t to expiration date $t+\tau$ is given by

$$r_{t+\tau}^{\text{Long,USD}} = \left(1 + r_{t+\tau}^{\text{Long,Local}}\right)\frac{S_t}{S_{t+\tau}} - (1 + r_{f,t+\tau}), \tag{2.3}$$

where $r_{t+\tau}^{\text{Long,Local}}$ is a long option straddle return in local currency, S_t is the foreign exchange rate in currency units per US dollar and $r_{f,t+\tau}$ is the US risk-free rate. The short straddle return is minus the long straddle return, $r_{t+\tau}^{\text{Short,USD}} = -r_{t+\tau}^{\text{Long,USD}}$. The straddle return in local currency is given by

$$r_{t+\tau}^{\text{Long,Local}} = \frac{(X_{t+\tau} - K_C)^+ + (K_P - X_{t+\tau})^+}{C_t + P_t} - 1, \tag{2.4}$$

where $X_{t+\tau}$ is the exercise-settlement value of the option product at expiration, whereas K_C and K_P are the call and put strike prices, respectively. C_t and P_t are the call and put option prices at the time the position is opened. For each option product, I take into account anticipated settlements due to non-trading days. In case of missing special exercise-settlement value, I use the underlying cash index level by following the option contract specification rules for this exception. All the option straddles returns are adjusted for splits by following the rules of the exchanges, which imply adjusting the strike prices by the amount by which the index is split.

For each pair of ETP-index option products, the dispersion trading return is given by

$$r_{t+\tau}^{\text{Dispersion}} = r_{t+\tau,\text{ETP}}^{\text{Short,USD}} - r_{t+\tau,\text{Index}}^{\text{Short,USD}}, \tag{2.5}$$

where $r_{t+\tau,\text{ETP}}^{\text{Short,USD}}$ is the short straddle return of an ETP option product and $r_{t+\tau,\text{Index}}^{\text{Short,USD}}$ is the short straddle return of the corresponding index option product. The dispersion trading return is a long-short portfolio.

All option and volatility returns are multiplied by 7%. This scaling approximately ensures to fulfill margin requirements and margin calls over the option holding period. This deleveraging is consistent with the literature. Santa-Clara and Saretto (2009) and Doran et al. (2013) use 7% to 10% of portfolio value in writing ATM options. By scaling the option returns, I implicitly assume a prefect FX hedge on the margin account.[13]

[13]Nonetheless, market-makers, hedge funds and proprietary trading firms may achieve greater leverage by means of the new portfolio margining rules of the CBOE and risk-based margining rules of European and Asian exchanges. See http://www.cboe.com/aboutcboe/cboe-cbsx-amp-cfe-press-releases?DIR=ACNews&FILE=20061213.doc. Further procedures regarding data and methodology are discussed in Appendix 2.7.1

2.5 Results

This section presents the main empirical findings of this paper. To start with, Subsection 2.5.1 analyzes the cross-sectional pricing of international and domestic option portfolios. Subsection 2.5.2 quantifies the dispersion trading risk premium of international and domestic option returns. Subsection 2.5.3 then considers the cross-section of ETP and index options separately, both in international and in domestic markets. Subsection 2.5.4 investigates the relation between option and volatility returns by means of Fama-MacBeth regressions. Then, Subsection 2.5.5 analyzes ex-ante and ex-post volatility returns overreaction of the considered option portfolios. Subsection 2.5.6 reports the impact of liquidity and transaction costs on cross-sectional and dispersion trading option strategies. Lastly, Subsection 2.5.7 considers robustness and extensions.

2.5.1 Cross-Section

This section investigates the pricing in the cross-section. I use two different universes: international and domestic. Within each of them, ETP and index options are considered. The following sorting analysis shows that the cross-section of international option returns is systematically mispriced. This effect is only marginally shared by the cross-section of domestic option returns.

Figure 2.3 and Table 2.2 analyze the cross-sections of international and domestic option returns by reporting unconditional, high tercile, low tercile and high minus low (long-short) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. All conditional portfolios are sorted by previous day IV or VSR volatility returns. The first three panels of Figure 2.3 show annualized average return in percent, alpha t-statistic with respect to the domestic equity six factors model and annualized Sharpe ratio. The last three panels report annualized standard deviation in percent, skewness and CAPM-β t-statistic with respect to CRSP value weighted index (henceforth CAPM-β).[14] [15]

International long-short option portfolios depicted in blue in the figure yield economically large average returns. This effect is only modestly present among equivalent domestic long-short option portfolios, drawn in green. Specifically, international long-short option portfolios deliver annualized average returns between 16.38% and 18.52%, with t-statistics of 5.82 and 6.87. The risk-adjusted returns confirm the pattern in the data ranging between 17.92% and 19.65%, with t-statistics varying from 6.49 to 7.29. Consistently, international Sharpe ratios are remarkable, varying between 1.83 and 2.29. By contrast, the returns from applying the same long-short strategy to domestic assets are much lower. The average returns range between 3.64% and 5.04%. Similarly, the mean t-statistic is weaker and approximately 2. Along these lines, the Sharpe ratio is considerably smaller varying between 0.56 and 0.67. Taken together, these results show that international long-short option portfolio returns are both statistically and economically significant. In contrast, domestic long-shot portfolios have comparably small returns and share only weakly the international volatility spread.

The results for the international sample show that volatility returns are very effective at selecting options with low and high expected returns. In international long-short option portfolios, the largest

[14] Newey and West (1987) standard errors computed with three lags are used throughout the entire paper to account for heteroskedasticity and autocorrelation.

[15] CAPM-β t-statistic with respect to MSCI world index is similar to the one reported for CRSP.

fraction of average return profitability comes from the short leg (high-basket), whereas the long leg (low-basket) plays a hedging role. Specifically, the short lag accounts for at least 85% of the long-short average return. Accordingly, these sorts yield larger returns and Sharpe ratios than a mere short position in an unconditional option basket. The unconditional international (domestic) option portfolio has an annualized average return of 5.39% (6.76%), a mean t-statistic of 1.17 (1.05) and Sharpe ratio of 0.32.[16] It is known that shorting volatility generates good returns. Yet, international long-short option portfolios yield greater average and risk-adjusted returns than unconditional short option strategies.

Despite their substantial average returns, international long-short option portfolios have low volatility, positively skewed returns and no exposure to market returns. The low risk characteristics of these portfolios are even more puzzling when compared to unconditional, high and low tercile portfolios. These unhedged portfolios exhibit standard deviations that are twice as high and negatively skewed returns. The risk characteristics of international option returns are presented in the last three panels of Figure 2.3 and Panels (B) and (C) of Table 2.2. Specifically, international long-short option portfolios have annualized standard deviations between 8.10% and 8.93%, skewness between 0.37 and 0.60 and maximum monthly drawdown between -5.96% and -3.67%. By contrast, the international unconditional option portfolio has a standard deviation of 16.97%, a strongly negative unconditional skewness of -3.03 and a maximum monthly drawdown of -25.47%. High and low baskets have risk characteristics similar to the unconditional portfolio, but they differ in average return. International long-short portfolios have low excess kurtosis between 0 and 1.56, which is approximately normal. On the other hand, the international unconditional, high and low portfolios exhibit an excess kurtosis between 8.16 and 12.73. These stylized facts between international long-short and (un)conditional portfolios show a cross-sectional mispricing among international options.

To gauge whether these attractive returns represent a compensation for risk, I compute the portfolio market exposure. I show the absence of CAPM-β risk for long-short international portfolios. Their betas range between -0.16 and -0.01, with t-statistics of -3.41 and -0.19. On the other hand, CAPM-β risk is present in unconditional, high and low international baskets, betas (t-statistics) ranging between 0.46 and 0.66 (3.63 and 4.62). The market neutrality of international long-short portfolios is not surprising on the basis of the delta and gamma values at the moment of portfolio formation. International long-short option portfolios delta (gamma) ranges between -0.06 and -0.03 (0.03 and 0.12). Whereas the (un)conditional high and low portfolios have delta (gamma) ranging between 0.37 and 0.42 (0.09 and 0.21). In short, international long-short option returns are remarkable for being zero-beta portfolios.

2.5.1.1 Is the Anomaly Spanned by Common Risk Factors?

To investigate the potential sources of these international option returns, I run factor model regressions. In these time-series regressions, the dependent variable is the return on an international or domestic long-short option portfolio sorted either by IV returns or VSR returns. The independent variables span over the following factor models. (i) Domestic equity factors model, (ii) international equity factors model, (iii) the corresponding unconditional (U) short option portfolio returns, (iv) a hedge fund short volatility (SV) factor and (v) a hedge fund relative volatility value (RV) factor. While running

[16] CRSP and MSCI mean t-statistics are about 1 as well over the same time period.

regressions with volatility factors, I control for equity exposure either internationally or domestically depending if the dependent variable is an international or domestic long-short option portfolio. Whenever a volatility regressor is included, the market factor is excluded from the control variables due to collinearity between volatility and market factors. Table 2.3 presents risk-adjusted returns and factor exposures from this analysis.

International long-short option portfolios deliver substantial risk-adjusted returns with respect to all equity and volatility factor models. In contrast, the risk-adjusted returns of the domestic long-short portfolios are considerably smaller.

Specifically, annualized abnormal returns (t-statistics) on international long-short portfolios range between 16.36% and 19.86% (5.12 and 7.45), whereas the annualized alphas (t-statistic) on domestic long-short portfolios range between 2.59% and 7.28% (1.01 and 3.12). Thus, international abnormal returns are two to three times larger than domestic ones.

Table 2.3 reveals that the returns on international and domestic long-short portfolios are mainly exposed to few factors. International long-short option portfolios have a negative exposure to the Fama-French robust minus weak (RMW) factor and a positive exposure towards the momentum factor, which are both statistically significant at the 5% level. The factor exposures imply that a one standard deviation increase in RMW (momentum) factor decreases (increases) the international long-short option portfolio return by about 55 (50) basis points per month. This factor exposures imply that international long-short option portfolios suffer (benefit) from increasing operating profitability (momentum) among international stocks.

Domestic long-short option portfolios have negative exposure to the hedge fund short volatility (SV) factor, which is not the case for the international long-short option portfolios. The SV factor exposure implies that a one standard deviation increase in SV factor decreases the domestic long-short option portfolio return by about 37 to 56 basis points per month, with a statistical significance between 10% and 5% level. This SV factor exposure among domestic long-short option portfolios implies that hedge funds take net short volatility exposure among domestic derivatives but neglect the possibility of doing so internationally.

2.5.1.2 Is the Mispricing Pervasive?

To investigate the extensiveness of the international mispricing, I analyze its time series properties. To do so, international and domestic long-short option portfolios are studied together with their unconditional option strategy as a function of when portfolios are constructed. These option strategies are constructed on the n^{th}-1 day and trades are executed on the n^{th} day, after the last third Friday of the month. Figure 2.4 presents the generality of the cross-sectional mispricing. In this Figure the x-axis represents the first 15 business days following the last third Friday of the month. The y-axes report: annualized average return in percent, the abnormal return t-statistic with respect to Fama and French (2015) plus Carhart (1997) factor model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

First, the international cross-sectional mispricing is present at each point in time. The domestic mispricing is systematically weaker than the international one. Specifically, throughout different points in time international long-short option portfolios have average returns ranging between 15% and 25%. Risk-adjusted return t-statistics range between 4 and 10 and Sharpe ratios vary between 1.5 and 3. On the other hand, domestic long-short option portfolios exhibit weaker pattern in the data, yielding an average return between 2% and 10%. Along the same line, the risk-adjusted return t-statistics vary between 2 and 4 and the Sharpe ratios between 0.5 and 1.5. Both international and domestic long-short option portfolios have larger returns and Sharpe ratios closer to the option contract expiration date. These stylized facts show that the difference between high and low straddle terciles is systematically larger internationally than domestically. This conclusion holds independently of which time the sorting is done.

Second, international long-short option portfolios are systematically less risky than unconditional option portfolios at each point in time. This low risk is puzzling, in light of the larger returns exhibited by the former portfolios over the latter ones. In particular, the standard deviation of international long-short option portfolios is below 12%, their skewness is systematically positive and CAPM-β t-statistics range between -4 and 0. Different risk characteristics are shown by unconditional option strategies, which have a standard deviation steadily above 15%. Consistently, the unconditional option returns are negative skewed and the CAPM-β t-statistics ranges between 0 and 5. The discrepancy between higher moment risks among international long-short and unconditional portfolios confirms the hypothesis of an international anomaly.

To summarize, the cross-section of international option returns is systematically mispriced. The international long-short option returns are an anomaly and not a compensation for risk.

2.5.2 Dispersion Trading

Are international ETP options more expensive than their corresponding index options? This section documents a positive risk premium between ETP and index options internationally. The dispersion premium increases in ex-ante volatility return gap between these two instruments. These findings are not always shared by equivalent domestic derivatives.

Figure 2.5 and Table 2.4 document the dispersion trading risk premium of international and domestic option returns by reporting statistical performance metrics for unconditional, high, low and long-short dispersion trading portfolios. Conditional portfolios are sorted by previous day ETP-index volatility returns difference, equation (2.2). Figure 2.5 displays annualized average return in percent, alpha t-statistic with respect to the domestic equity factors model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

International (domestic) high dispersion trading portfolios yield large (small) annualized average returns, as depicted in the top panel of Figure 2.5.

First, international high dispersion trading annualized average returns range from 24.97% to 26.23%. Risk-adjusted returns are as large and exhibit t-statistics between 7.00 and 7.19. Along the same line, annualized Sharpe ratios range between 2.03 and 2.25. This empirical evidence outlines a stunning difference between ETP and index option returns behavior. A completely different picture emerges for domestic high dispersion trading option portfolios, which annual returns span between 1.48% and 1.98%. Domestic Sharpe ratios are tiny, ranging between 0.14 and 0.19.

Second, I test if international high dispersion trading portfolios generate economically large returns in excess of the low dispersion trading tercile. On average, the international long-short dispersion trading option portfolios yield annualized average returns (mean t-statistic) ranging between 11.48% and 14.73% (4.54 and 5.92).[17] In line with this evidence, risk-adjusted returns and their t-statistics are of the same economic and statistical magnitude, alpha (t-statistic) ranging between 11.51% and 15.62% (4.06 and 6.08). This substantial difference between international high and low dispersion trading terciles implies that sorting ETP-index pairs by ex-ante volatility returns adds value to the unconditional dispersion trading strategies.

Third, international high dispersion trading portfolios outperform the unconditional dispersion portfolios, as illustrated in Figure 2.5. The international high dispersion trading average return is approximately twice the international unconditional one; $\frac{26.00\%}{12.60\%} \approx 2$. Similarly, the international high tercile Sharpe ratio is approximately 57% higher than the Sharpe ratio shown by the international unconditional basket; $\frac{2.25}{1.43} \approx 1.57$. It is worth noticing that the international unconditional dispersion trading Sharpe ratio is 1.43, whereas the domestic case has a Sharpe ratio merely of 0.43. Accordingly, this different behavior between international and domestic baskets, even at the unconditional level, outlines the presence of a risk premium among ETP and index options internationally and none or weaker in the domestic derivative space.

International high dispersion trading returns are exposed to volatility and skewness risks, but have low market risk. Accordingly, international high dispersion trading portfolios command a positive risk premium for their systematic exposure towards high moment risks. The last three panels of Figure 2.5 and Panels (B) and (C) of Table 2.4 report the risk pattern in the data.

First, international high dispersion trading option portfolios are exposed to large volatility risk. Specifically, their standard deviation is 40% higher than what is exhibited by the unconditional dispersion trading strategy; $\frac{12.32\%}{8.78\%} \approx 1.40$. Consistently, the international unconditional dispersion trading standard deviation is 28% higher than what is shown by the unconditional domestic basket; $\frac{8.78\%}{6.83\%} \approx 1.28$. Hence, there is a decreasing volatility risk from high dispersion to unconditional dispersion and from international to domestic dispersion.

Second, dispersion trading portfolios are exposed to skewness risk. The international high (unconditional) dispersion trading skewness is negative and ranges between -0.92 and -0.48 (-0.56). Similarly the minimum monthly return for international high dispersion trading portfolios is twice as large as the unconditional dispersion minimum monthly return; $\frac{-14.22\%}{-7.14\%} \approx 2$. This implies that dispersion trades are exposed to steep drawdowns.

Third, high dispersion trading portfolios have low exposure to market risk. This approximate neutrality is consistent with the feature of being short ETP contingent claims and long index derivatives, which offset the market exposure. Specifically, high dispersion trading portfolios have a CAPM-β ranging between 0.07 and 0.10 with t-statistic of 0.99 and 1.89.

To sum up, high moment risks are priced beyond market risk. Heterogeneity between international ETP and index options regarding exercise-settlement value and AM / PM settlement lead to an increase in hedging risk. These non-linear risks are present between assets that at first glance are similar but institutionally are not.

[17] A dispersion trading return is a self-financing portfolio. Thus, only w and $1-w$ fraction of the high and low dispersion terciles can be combined.

2.5.2.1 Underlying Pairs Comovement

International ETP and index options differ in their product specifications. First, their underlying assets are not the same. Second, these instruments are quoted in different currency and venue. These differences are smaller among domestic pairs.

The market capitalization of the international underlying assets might differ to some degree. For instance, MSCI Korea ETP covers approximately 85% of the Korean equity universe. While KOSPI 200 index covers approximately 93% of the total stocks market value of the Korea exchange.[18] This is not the case at the domestic level in which the underlying market capitalization is similar for ETP and index options, e.g. S&P100 ETP iShares and S&P100 index.

International index underlying assets and options are exchanged in local currency and in their country's exchange. By contrast, international ETP underlying assets and options are traded in USD through the CBOE. The different currency and venue between international ETPs and indexes lead to an increasing hedging risk between the corresponding derivative instruments. In contrast, domestic ETP and index underlying assets and options are both exchanged in USD and on the CBOE.

To highlight the difference in systematic behavior between international ETP and index underlying assets, I analyze the cross-sectional distribution of their correlations. Panel (A) of Figure 2.6 shows the cross-sectional distribution of underlying return correlations for international and domestic ETP and index pairs. Panel (B) shows the distribution of the difference between the upper and lower bound of these estimated correlations at the 95% confidence level. These correlations are estimated by full-sample daily returns in USD between ETP and index pairs underlying assets for the period 2006-2015.

The international underlying assets comove less than the domestic ones, as depicted in Panel (A) of Figure 2.6. Precisely, the median (mean) correlation between international pairs is 0.73 (0.69), whereas is 0.94 (0.92) for the domestic ones. Along the same line, Panel (B) shows grater estimation uncertainty in realized correlation among international underlying assets than among the domestic ones. Internationally, the median (mean) difference between upper and lower bound is 0.035 (0.038), while domestically is 0.01 (0.009). Thus, the uncertainty in estimated correlations is about three times larger internationally than domestically.

Institutional differences between international ETP and index underlying assets increase the hedging uncertainty. ETP and index options may move distinctively in turbulent environments. Intuitively, a correlation premium should be priced between contingent claims that exhibit heterogeneous comovement.

2.5.2.2 Are the Returns Abnormal?

To understand the sources of these return differences, I further investigate risk-adjusted returns and factor exposures of international and domestic high dispersion trading option portfolios. I run time series regressions in which the dependent variable is a return on an international or domestic high dispersion trading portfolio. These portfolios are formed by sorting either by IV returns or VSR returns. The factor models used as independent variables are: (i) domestic equity factor model, (ii) international equity factor model, (iii) the corresponding unconditional dispersion trading portfolio of the dependent variable, (iv) hedge fund short volatility (SV) index and (v) hedge fund relative volatility value (RV)

[18] The market capitalization sources are: MSCI website and KRX exchange.

index. Table 2.5 shows the results of this analysis.

International high dispersion trading option portfolios have substantial risk-adjusted returns with respect to any considered model. Furthermore, they have positive exposure to the unconditional dispersion trading factor and the market factor. By contrast, domestic high dispersion trading portfolios have statistically insignificant risk-adjusted returns with respect to any considered factors model.

Specifically, the findings are the following. First, international high dispersion trading option portfolios exhibit annualized alphas ranging between 12.00% and 25.00%. These abnormal returns are all statistically significant at the 1% level. In contrast, domestic high dispersion trading option portfolios show risk-adjusted returns varying between -2.00% and 2.70%, which are all statistically insignificant at the 10% level.

Second, international high dispersion trading option portfolios have a remarkable exposure to the corresponding unconditional dispersion trading factor. These beta estimates are statistically significant at the 1% level. This factor exposure implies that a one-standard-deviation increase in the unconditional dispersion trading factor increases the international high dispersion trading portfolio return by about 200 to 240 basis points per month. In contrast, international high dispersion trading option portfolios have relatively low exposure to the market factor. Only the dispersion portfolio sorted by VSR returns exhibits a statistically significant exposure at 5% level. This factor exposure implies that a one-standard-deviation increase in the market factor increases the international high dispersion trading portfolio return by 69 basis points per month.

Third, domestic high dispersion trading portfolio sorted by VSR returns has positive factor exposure to the short volatility hedge fund index. The factor exposure is statistically significant at the 5% level. Contrary, there is no such factor exposure to any international high dispersion trading portfolio. This means that hedge funds taking short volatility bets are more prone to use domestic derivatives, while ignoring the international derivative space.

2.5.2.3 The Generality of Dispersion Trading Risk Premium

After identifying which dispersion pairs are systematically more expensive, I investigate how their return and risk characteristics change over time. Figure 2.7 documents the time series properties of international and domestic dispersion trading option returns, both for high and unconditional baskets. These option strategies are constructed on the n^{th}-1 day and trades are executed on the n^{th} day, after the last third Friday of the month. The x-axis of Figure 2.7 represents the first 15 business days following the last third Friday of the month. The y-axes report annualized average returns in percent, abnormal return t-statistic with respect to the domestic equity factor model, annualized Sharpe ratio, annualized standard deviation in percent, skewness and CAPM-β t-statistic.

International high dispersion trading risk premium is pervasive at each point in time and is a compensation for systematic volatility risk, as shown in Figure 2.7.

First, international high dispersion trading portfolios have large returns, for all portfolio formation dates considered. Specifically, annualized average returns range between 20% and 30%, abnormal returns t-statistics between 3 and 7, and annualized Sharpe ratios between 1 and 2.5. On the other hand, the domestic option returns are systematically smaller.

Second, international high dispersion trading portfolios are exposed to systematic volatility and skewness risks, but only marginally to market risk. International high (unconditional) dispersion trading standard deviations range between 10% and 20% (5% and 11%). In the same manner, international high dispersion trading standard deviation is larger than the domestic equivalent volatility risk, which relative difference can vary from 5% to 90%. Additionally, international high dispersion trading portfolios have negative skewness risk ranging between -1 and 0. In contrast, international high dispersion portfolios rarely reject the null hypothesis of a zero CAPM-β, which t-statistics varying between 0 and 2.

Third, the volatility of international high dispersion trading portfolios depends on the time of portfolio formation. Their standard deviations are higher between the first and the second Friday of the expiration month (corresponding approximately between days 10 and 15 in Figure 2.7). This variability is driven by heterogeneity in expiration days between Asian ETP and index options. While ETP options expire on the third Friday of the month, Asian index options generally do not. For instance, Korean and Japanese index options expire earlier, on the second Thursday and Friday of the month, than the corresponding ETP options. This structural divergence implies that the portfolios short ETP positions are unhedged for about a week's time. To show how these institutional differences affect the risk of these portfolios, I run the analysis excluding the following Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong ones. The results in Figure 2.7.1 show that the dispersion trading pattern is robust to the exclusion of these indexes. However, the standard deviation of high dispersion trading portfolios between the first and second Friday of the month is much lower. Specifically, without Asian indexes the standard deviation of international high dispersion trading portfolios barely exceed 15% at its peak.[19] In contrast, in the case of a comprehensive use of all the indexes the volatility risk ranges strongly between 15% and 20% at its peak.

To sum up, international high dispersion trading risk premium is large, pervasive and a compensation for systematic volatility. This volatility risk is related to heterogeneity in contract specifications across instruments. Generally, the dispersion premium is greater internationally than domestically.

2.5.3 ETP v.s. Index Options

This section considers ETP and index option returns separately, both for international and domestic markets. Subsection 2.5.3.1 analyzes the cross-sections of ETP and index option returns internationally. Subsection 2.5.3.2 investigates the cross-sections of ETP and index option returns domestically.

2.5.3.1 International ETP and Index Option Returns

Figure 2.8 and Table 2.6 present statistical performance metrics for the cross-sections of international ETP and index option returns separately. The cross-sections are analyzed by reporting unconditional, high, low and long-short option portfolios. The following sorting analysis shows that the long-short returns are substantially larger for ETP options than for index options. In addition, the absence of volatility, skewness and market risks among long-short portfolios confirm a cross-sectional mispricing explanation. Interestingly, this larger profitability of ETP options is not driven by market segmentation. All international ETP options are exchanged through the CBOE and in USD.

[19] Figure 2.7.2 shows the consistency and robustness of the cross-sectional mispricing without Asian indexes.

First, annualized average returns of international ETP long-short option portfolios range between 19.83% and 20.30%. Their risk-adjusted returns with respect to the domestic factor model vary between 19.69% and 21.15%, with t-statistics of 4.86 and 5.69. Their annualized Sharpe ratios range between 1.66 and 1.72. Even if international index options show analogues pattern in the data, their returns are much smaller. Specifically, the annualized average returns of index option high minus low portfolios range between 6.36% and 8.01%. Their Sharpe ratios only lie between 0.47 and 0.71. This empirical evidence underlines a larger systematic spread among ETP options returns than among index options returns.

Second, international ETP long-short (unconditional) option portfolios have low (high) risk, as Figure 2.8 indicates in the last three panels. Specifically, ETP long-short option portfolios annualized standard deviations vary between 11% and 12% (18.22%), while skewness ranges between 0.51 and 0.57 (-2.84). Similarly, their excess kurtosis fluctuates between 0.55 and 2.21 (10.13) and CAPM-β t-statistics range between -1.63 and 0.37 (4.07).

Third, the difference in unconditional ETP and index option returns support the hypothesis of an international dispersion premium. Concretely, the unconditional ETP options basket annualized average return is 10.93% with a mean t-statistic of 2.29. Opposed to the unconditional index options basket annualized average return which is -2.15% with a mean t-statistic of -0.45.

Details of the risk-adjusted returns and factor exposures of cross-sectional long-short ETP and index option portfolios are presented in Table 2.7. These time series regressions use as dependent variable the return on an ETP or index long-short option portfolio sorted either by IV returns or by VSR returns. These regressions use as independent variables one of the following factor models: (i) domestic equity factors model, (ii) international equity factors model, (iii) the corresponding unconditional options portfolio return, (iv) hedge fund short volatility (SV) index and (v) hedge fund relative value volatility (RV) index.

The main result in Table 2.7 is that international ETP long-short option portfolios have abnormal returns with respect to all factor models. On the other hand, international index options have sporadic abnormal returns. Specifically, the annualized abnormal returns of international ETP (index) options range between 17.00% and 22.00% (3.60% and 9.30%), with t-statistics between 3.40 and 5.70 (0.80 and 2.90).

Lastly, international index long-short option portfolios have three statistically significant factor exposures, namely to the domestic market, momentum and value factors. The market factor exposure is negative and statistically significant at the 1% level. In contrast, momentum and value beta estimates are positive and statistically significant at the 5% level. These factor exposures imply that a one-standard-deviation increase in the momentum (value) factor increases the international index long-short option portfolio return by 88 (72) basis points per month. This effect means that international index options are indeed affected by momentum (value) in the US equity stock market. In contrast, neither ETP nor index long-short option portfolios have exposure to any hedge fund factors.

2.5.3.2 Domestic ETP and Index Option Returns

This subsection presents results from performing a similar analysis as in subsection 2.5.3.1, but now for domestic ETP and index options. Figure 2.9 and Table 2.8 report return and risk characteristics for the cross-sections of ETP and index option returns, separately. The results differ remarkably from those in the international sample in three main respects: domestic ETP or index long-short option portfolios yield moderate returns, their statistical significance is relatively weak and hedge funds have exposure toward domestic derivative products.

First, there is no clear systematic pattern across portfolio average returns in Figure 2.9. Specifically, the annualized average returns of ETP (index) long-short option portfolios vary between 3.29% and 5.59% (0.92% and 3.42%), have t-statistic of merely 1.44 and 1.99 (0.37 and 1.33), and Sharpe ratios between 0.43 and 0.60 (0.09 and 0.37).

Second, further analysis on risk-adjusted returns and factor exposures reveal similar return pattern but additional insights on hedge funds' derivative use, as Table 2.9 shows. Both ETP and index long-short option portfolios deliver sporadic statistically significant risk-adjusted returns when benchmarked against most models. Concretely, ETP long-short annualized abnormal returns (t-statistics) range between 0.30% and 6.92% (0.12 and 2.34). Index long-short annualized risk-adjusted returns (t-statistics) range between 1.61% and 6.93% (0.63 and 3.19).

Third, both domestic ETP and index long-short option portfolios have an exposure to the SV and RV hedge fund factors, statistically significant at the 10% to 1% level. Index long-short option portfolios are negatively exposed to the hedge fund short volatility (SV) factor. The SV factor exposure implies that a one-standard-deviation increase in SV factor decreases the domestic index long-short option portfolio return by about 100 to 116 basis points per month. Even more interesting is the positive (negative) exposure of long-short ETP (index) option portfolios to the RV hedge fund index. The RV factor exposure of the ETP (index) portfolios implies that a one-standard-deviation increase in RV factor increases (decreases) the domestic ETP (index) long-short option portfolio return by about 40 (50) basis points per month. These factor exposures imply that relative volatility funds arbitrage ETP and index options. Surprisingly, it seems that these funds are not exploiting international differences in option richness.

To further test the hypothesis that volatility hedge funds have exposure towards domestic derivative products, but not among the international ones, I do the following. For both of the volatility indexes SV and RV, I run univariate time-series regression on all the cross-sectional long-short and high dispersion trading strategies considered so far in the paper. Then, the estimated factor loadings are plotted as a function of their t-statistics in Figure 2.10. This figure shows that volatility funds do have an exposure towards domestic option strategies. Nonetheless, none of the factor loadings of international option portfolios are statistically significant at the 10% level.

To summarize the results up to this point, I document that the cross-sectional mispricing is mainly concentrated among international ETP options, moderately among international index options and only sporadically among domestic derivative products. Additionally, I show a discrepancy between international ETP and index option returns, at the unconditional level, supporting the presence of an international dispersion premium. Lastly, I document that volatility hedge funds, among the two considered indexes, are exposed towards domestic derivative products, while neglecting the possibility of engaging in international volatility arbitrage.

2.5.4 Options and Volatility Returns: Fama-MacBeth Regressions

The results until now have shown a strong predictability of ex-ante volatility returns for international option returns, by means of univariate sorts. Nevertheless, further specific option product characteristics may be important determinants of the cross-sectional variation in international option returns. Accordingly, volatility returns may be subsumed by other variables. To further explore the predictive power of volatility returns for future option returns, while controlling for specific option characteristics, I estimate Fama and MacBeth (1973) regressions. This section shows that volatility returns are an important determinant of the cross-sectional variation of option returns. This predominance holds with and without controls. Furthermore, the cross-sectional predictability of volatility returns is statistically and economically more pronounced internationally than domestically, hence confirming the results so far.

Specifically, each month I run cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{2.6}$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on product i at expiration day $t+\tau$. Volatility $\text{Return}_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. Λ_t is a column vector of controls coefficients. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. The underlying asset's skewness and kurtosis estimated from daily data over the previous year. The underlying asset's momentum estimated as the cumulative return over the last twelve months skipping the most recent month. Market beta and coskewness beta estimated from an univariate regression of the underlying asset's returns on previous year market index daily returns and squared returns, respectively. The market index is either MSCI or CRSP index depending if the option underlying asset is an international or domestic security. Additional control variables include: absolute delta, dollar volume, dollar open interest and bid-ask spread average between call and put options used to construct the straddle.[20] [21] Lastly, I report the time-series average of the estimated coefficients together with their Newey and West (1987) t-statistics computed with three lags. Alternative regression specifications are discussed in the robustness section.

Table 2.10 reports the regression results for the cross-sections of international and domestic option returns. For the international sample the volatility coefficients are positive and highly statistically significant, both with and without controls. Regarding economic significance, a one standard deviation increase in volatility return implies an increase in option returns of 76 to 78 basis points per month,

[20] The bid-ask spread is assumed to be zero in case of missing value. Results are robust to the exclusion of those securities for which the bid-ask spread is missing.

[21] Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are standardized to unit variance.

with t-statistic ranging between 6 and 8. Domestic volatility return coefficients are positive and statistically significant. Yet, they have lower economic and statistical magnitude than the international ones. Specifically, the domestic volatility return coefficients range between 23 and 38 basis points per month with t-statistics between 3 and 4. The predictability of international volatility returns is larger than the domestic equivalent, as illustrated in Panel (A.1) of Figure 2.11. This plot shows Fama-MacBeth volatility return coefficients as a function of their t-statistics, with and without control variables. In addition, international volatility returns have the largest economic magnitude and statistical significance with respect to any of the control variables considered in multivariate regressions. The control coefficients are plotted as a function of their t-statistics in Panel (A.2) of Figure 2.11. These facts imply that volatility returns are one of the main determinants in explaining the cross-sectional variation of option returns, especially at the international level.

Table 2.11 reports Fama-MacBeth regression results for international and domestic dispersion trading pairs. In these regressions the left hand side variable is a dispersion trading option return, equation (2.5). For each international or domestic cross-section of dispersion pairs, the main variable of interest is the IV or VSR dispersion return, equation (2.2). Consistently, all the control variables are the difference between the ETP and index variables.

The key finding is that dispersion trading volatility return coefficients are economically large and statistically significant internationally, whereas they are not domestically. Specifically, a one standard deviation increase in dispersion trading volatility return implies an increase of 136 basis points in next month international dispersion trading option returns. When including control variables the volatility returns coefficients range between 80 and 140 basis points, with t-statistics between 3 and 7. By contrast, domestic dispersion trading volatility returns do not have any predictive power for domestic dispersion option returns. None of these coefficients is statistically significant at the 10% level. The striking difference in return predictability between international and domestic dispersion trading volatility returns is shown in Panel (B.1) of Figure 2.11, in which coefficients are plotted as a function of their t-statistics. The different systematic behavior of ETP and index options internationally is driven by volatility deviations, while this is not the case among domestic derivative products.

To further inspect the main source of volatility return predictability, I run Fama-MacBeth regressions on ETP and index straddle return cross-sections, at the international level. Volatility return coefficients are economically larger for ETP options, while they are smaller for index options, as Panel (A.1) of Figure 2.12 shows. While the volatility return coefficients range between 70 to 100 basis points per month for ETP options with and without controls, index options coefficients barely reach 30 to 50 basis point per month and statistical significance when controls are included, as Table 2.12 reports. This implies that volatility returns have greater cross-sectional predictability among international ETP derivatives, t-statistic about 6.5, than among international index options, t-statistic about 2.6.

Along the same line, I run Fama-MacBeth regressions for domestic ETP and index option cross-sections. Also at the domestic level the largest cross-sectional predictability of volatility returns is concentrated among ETP options rather than among index options as shown in Panel (B.1) of Figure 2.12 and Table 2.13. Nevertheless, the volatility return coefficients of ETP options domestically are substantially smaller than the ones for the international ETP options. Specifically, a one standard deviation increase in volatility returns domestically implies 20 to 40 basis points higher domestic ETP option returns next month. In contrast, for international ETP options their coefficients are about 100 basis points per month. These facts underline a difference in option products behavior among international and domestic derivatives with respect to volatility deviations across securities. Thus, exploiting volatility return deviations in the international cross-section is more successful than doing so in the domestic one.

In short, Fama-MacBeth regressions confirm the pattern in the data characterized by the sorting analysis. Volatility returns are strong predictors of future option returns internationally, with and without controls. While domestic volatility return predictability is weaker.

2.5.5 Volatility Returns Overreaction: From Ex-Ante To Ex-Post

So far, the data have shown that ex-ante volatility returns have a stunning predictability for future straddle returns, both across and between options. Having said that, a natural question arises. What is the excess implied price of options over their holding period? This section analyzes the economic magnitude of ex-ante and ex-post volatility returns. The key findings are the following. First, there is a pronounced cross-sectional variation of ex-post volatility returns across and between international options. Second, this ex-post variability is less pronounced among domestic volatility returns. Third, international ETP options exhibit the largest variation. These findings of implied volatility overreaction are consistent with previous empirical evidence in the academic literature. For example, Poteshman (2001) finds that SPX options overreact to changes in the underlying instantaneous variance. Comparably, Goyal and Saretto (2009) find overreaction of implied volatility in the cross-section of US equity stock options.

International long-short option portfolios have large ex-ante and ex-post volatility return deviations, as shown in Panels (A.1) and (A.2) of Figure 2.13 respectively. The volatility return deviations at portfolio construction range between 29.74% and 41.70% on a yearly basis. On the other hand, the ex-post volatility returns vary between 14.39% and 29.11%. Even if there is volatility mean reversion between ex-ante and ex-post volatility returns, this reversion is too slow, making international options inconsistently priced. This volatility spread between high and low option portfolios implies that the top tercile of most expensive options has an excess price that is 14 to 29 percentage points higher than what is shown by the cheapest options. To put things into perspective, the domestic ex-post volatility return spread is considerably smaller ranging between 7.25% and 19.33%, as Table 2.14 shows. Ex-post volatility returns are 50% to 100% larger internationally than domestically. Accordingly, domestic options are more aligned with their future realization than the international ones, showing once more how the mispricing is concentrated internationally.

High dispersion trading portfolios show substantial volatility deviations between ETP and index options, internationally, as Figure 2.13 depicts in Panels (B.1) and (B.2). Specifically, high dispersion trading ex-ante volatility returns have deviations as large as 22.89% and 40.70% on an annual basis. Implying that country options on different underlying assets can exhibit remarkable different excess implicit prices. This ex-post volatility return difference can be up to 16.55% and 34.70%, among the top tercile of most heterogeneous derivative pairs. With smaller dispersion, domestic high dispersion trading ex-post volatility returns vary between 2.96% and 10.98%, as Panel (B) of Table 2.14 reports. Therefore, this ETP-index volatility return discrepancy makes the international high dispersion trading option portfolios likely to command a risk premium.

Among all the considered option products, international ETP options exhibit the largest cross-sectional variation in their ex-ante and ex-post volatility returns, as depicted in Figure 2.14. This fact shows how newly issued derivatives may be less understood and display lower speed of volatility arbitrage. Specifically, international ETP long-short portfolios have ex-ante (ex-post) volatility returns varying between 33.65% and 47.56% (19.98% and 37.42%) on an annual basis. Implying that the most expensive international ETP options are overpriced between 20 to 40 percentage points more than the cheapest ones. With smaller cross-sectional variation, all the other ETP and index options have their long-short ex-post volatility returns varying between 2% to 20%. In addition, international ETP options exhibit extraordinary elevated ATM implied volatility of 28. While all the other derivatives show an ATM implied volatility of about 20, as Table 2.15 reports. Comparing ETP and index volatility return deviations between international and domestic markets shows that the main pricing discrepancy is concentrated internationally and in ETP options.

2.5.6 Liquidity and Transaction Costs

The paper has shown that international option strategies yield larger returns than the domestic ones. Nonetheless, liquidity and transaction costs can decrease the profitability of option schemes substantially. How much of these returns are actually achievable? This section investigates the performance of cross-sectional and dispersion trading option strategies under market frictions. The key finding is that market participants able to execute trades at most at 25% of the effective to quoted spread may profitably exploit the pattern in the data. Specifically, with such a trade execution, international option strategies yield annualized average return ranging from 7% to 12% with a Sharpe ratio of about 1. In contrast, domestic strategies do not deliver positive returns, as Table 2.16 shows.

In the academic literature, the evidence regarding the impact of liquidity and transaction costs on option strategies is not conclusive. Researchers find both that option strategies may be driven by limit to arbitrage or that these strategies may be achievable only by a subset of professional investors. The academic literature reports the limit of contingent claim models under the constraints of real financial markets (Green and Figlewski (1999) and Figlewski (2017)). Similarly, most of the option strategies and irregularities documented appear restricted by liquidity and transaction costs (Figlewski (1989), Gould and Galai (1974), Ho and Macris (1984), Swidler and Diltz (1992), George and Longstaff (1993), Ofek et al. (2004), Goyal and Saretto (2009), Driessen et al. (2009), Cao and Han (2013b) and Koijen et al. (2017)), among which the bid-ask spread plays a prominent role. Yet, non-synchronous trading between derivative and underlying markets leads to a widening on the quoted spread at market close. Studies in the US equity stock option market show that the effective to quoted spread ranges from 50% to 100% (Mayhew (2002), De Fontnouvelle et al. (2003) and Battalio et al. (2004)). A recent paper in market microstructure shows narrower effective spreads for option execution timers (Muravyev and

Pearson (2017)). High frequency traders may be able to execute trades close to 10% of the effective to quoted spread, if not lower. Other market players, such as discretionary traders, on average can execute trades below 20% of effective to quoted spread. In addition, the liquidity of options and associated transaction costs have been improving in US index options and equity stock option markets, since mid 2000 (Muravyev and Ni (2016) and Christoffersen et al. (2017)).[22] Lastly, the annualized Sharpe ratio of volatility hedge fund indexes range between 0.86 and 2.41 over the sample period. This realized performance shows that professionals can exploit volatility deviations. Nonetheless, it seems that they neglect the possibility of engaging in foreign volatility arbitrage. In this section, I show that exploiting volatility deviations internationally may be better than doing so domestically even after moderate levels of market frictions.

As a result of data constraints, the sample does not have actual measures of effective spread. Accordingly, I study the profitability of option strategies by assuming the effective to quoted spread to be 0% (mid-price), 10%, 25%, 50%, 75% and 100% (as in Goyal and Saretto (2009), Koijen et al. (2017) and Cao et al. (2017)). For those options which bid and ask prices are not available, the closing trade price is used. For derivatives with physical delivery, the underlying is assumed to have negligible transaction costs. To alleviate liquidity concerns, the options selected at trade execution have either positive volume or positive lagged open interest. Whenever possible, the selected option is required to have positive bid price. Then, the closest strike to the ATM is selected. If none of the OTM options have such characteristics, the first ITM option is appointed with same methodology. The rest of the portfolio construction is as previously delineated.

Panel (A) of Figure 2.15 shows annualized Sharpe ratio of international and domestic cross-sectional strategies as a function of the effective to quoted spread. These strategies are long-short portfolios. The results under market frictions confirm the findings presented in the paper so far. International long-short option strategies yield larger Sharpe ratio than domestic equivalent scheme. Nonetheless, Sharpe ratio declines steadily with the widening of the effective to quoted spread. Specifically, when trades are executed at mid-price the Sharpe ratio ranges between 1.31 and 1.67 for international portfolios, while it varies between 0.33 and 0.62 for domestic option strategies. When trades are executed at 25% of the effective to quoted spread the Sharpe ratio ranges between 0.81 and 1.16 internationally, whereas it ranges between -0.04 and -0.25 domestically. Yet, any trade executed with an effective to quoted spread beyond 50% makes the strategy unprofitable, both internationally and domestically.

High dispersion trading option strategies deliver grater performance internationally than domestically, even with market frictions. Returns computed at mid-price deliver Sharpe ratio ranging between 1.50 and 1.64 for international portfolios, while it varies between 0.03 and -0.02 for domestic strategies, as Panel (B) of Figure 2.15 reports. When trades are executed at 25% of the effective to quoted spread the Sharpe ratio is reduced between 0.95 and 1.11 for international strategies, while it ranges between -0.18 and -0.26 for the domestic ones. However, any trade executed beyond 50% of effective to quoted spread makes the dispersion trading strategies unprofitable.

[22] Changes in regulation such as the option penny pilot program have improved liquidity in the US option market, since 2007-2008, see https://www.nyse.com/publicdocs/nyse/markets/arca-options/Penny_Pilot_Report_IV_VI.pdf

A consistent picture emerges from the liquidity and transaction costs analysis. International option strategies may lead to better performance than domestic ones. Yet, there is no limit to arbitrage only for those alternative investment funds which can execute their trades at most at 25% of the effective to quoted spread.

2.5.7 Robustness

To better understand the stability of the empirical findings, I present robustness checks regarding the results presented in the paper.

Sorting volatility measures: The portfolio strategies are robust to different sorting measures. Relative and absolute valuation measures between implied and realized volatility yield similar results, e.g. implied to realized volatility ratio and implied minus realized volatility. In addition, I test the estimation window of the realized volatility at the moment of portfolio formation. Any long term estimate of realized volatility performs equally good as the ones presented in the main body of the paper, e.g. between 6 months and 5 years back. Results become weaker whenever the realized volatility estimate is done on a too short sample, e.g. a month. Furthermore, sorting straddles or dispersion pairs by the volatility return average rank over the past one to ten days leads to similar results as the ones in the main body of the paper. Additionally, by increasing the number of baskets in portfolios sorting shows that option returns are larger among extreme basket portfolios.

Dispersion trading: I sort dispersion pairs by absolute dispersion trading volatility returns and swap ETP and index long / short straddle position on the sign of the deviation. There are few swaps and results are robust to this change.

Exchange rate and interest rate: I run all the tests of this paper by assuming an exchange rate equal to one for all the currencies and zero risk free rate while computing option returns. The economic magnitude of returns and their statistical significance are similar to the ones presented.

Time series regressions, holding period: I run time series regressions by using different holding periods of the equity factors. This allows to match approximately the holding period of the option portfolios. I consider the following holding periods: from the moment of portfolio entry to (i) the third Friday, (ii) the fourth Friday and (iii) the end of the expiration month. In addition, I consider running monthly time series regressions in (iv) calendar time. Realized option returns in a calendar month are matched with same calendar month factor return. Across all these alternatives, the abnormal returns and factor exposures keep same sign, similar economic magnitude and similar statistical significance as the ones presented in the paper. Annualized risk-adjusted returns may increase or decrease at most by ± 2%. Factor exposures may increase or decrease of at most by ± 20 basis points per month, and t-statistics may change at most by ± 1. My results are robust to this changes and the qualitative conclusion of the paper remains the same.

Fama-MacBeth regressions: I run Fama-MacBeth regressions by using as explanatory variables their cross-sectional rank as in Asness et al. (2017). Rank regressions ameliorate noisy estimates and outliers. The regression results are robust to this change.

2.6 Conclusion

In this paper, I present two new patterns in international option returns: a cross-sectional mispricing and a dispersion trading risk premium.

First, international option returns on ETPs and indexes reveal an asset pricing anomaly by sorting on ex-ante volatility returns. An international long-short option portfolio yields annualized risk-adjusted returns (Sharpe ratios) ranging between 16% and 20% (1.8 and 2). These returns have low volatility, positive skewness and absence of market risk. Consistently, I find large cross-sectional variation in ex-post volatility returns among international portfolios.

Second, international ETP options command a positive risk premium with respect to their corresponding index options. A high volatility spread portfolio between ETP and index option straddles produces substantial annualized risk-adjusted returns (Sharpe ratio) of 25% (2). This volatility spread between international ETP and index options is a compensation for systematic volatility risk, skewness risk and heterogeneity in option product specifications. Accordingly, I show sizable ex-post volatility returns deviations and contract specification discrepancies, e.g. expiration day and underlying asset comovement. These latter two features, among others, induce the presence of a risk premium which is not hedgeable.

Both of the systematic patterns in the data are widespread internationally, while they are modest domestically. Finally, I present evidence that volatility hedge funds are predominantly exposed towards domestic derivative products, while they neglect the possibility of engaging in foreign volatility arbitrage.

The main implications of this study are the following. To begin with, good returns may reside between securities that at first glance are similar, but institutionally are not. Exploring newly-issued derivatives may be an interesting path for unexplored returns. Lastly, alternative investment funds looking for abnormal returns may enlarge their interest towards international contingent claims. Decades of research has focused mainly on domestic option products. Future paths for research might explore institutional differences between equity stock options and contingent convertible bonds at the international level.

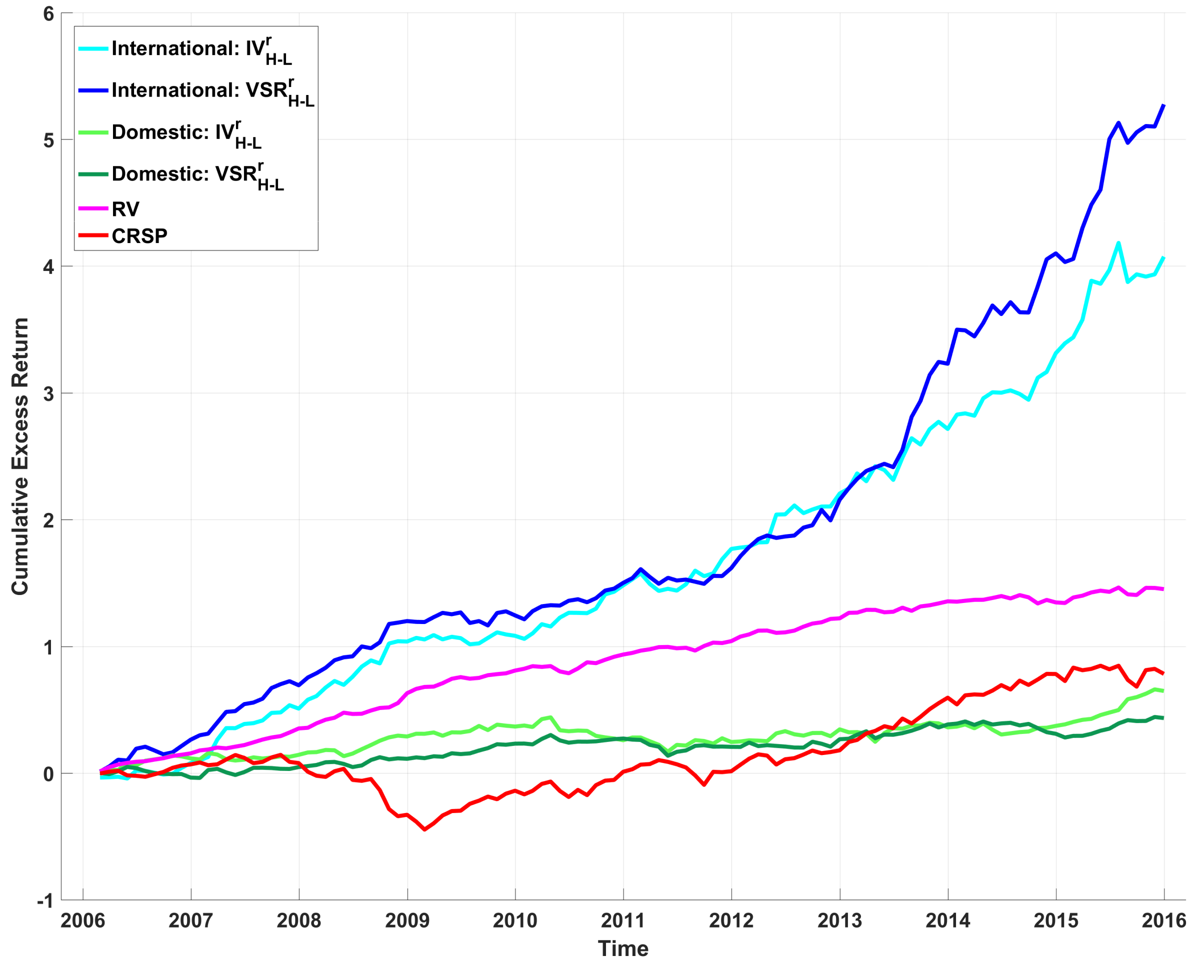

Figure 2.1

Cumulative Excess Returns of Cross-Sectional Long-Short International and Domestic Option Portfolios.

This figure shows cumulative excess returns of international and domestic cross-sectional long-short option strategies. Each month, international at-the-money (ATM) straddles are sorted by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. Then, the long-short (H-L) portfolio sells the expensive tercile and buys the cheap tercile. Domestic long-short portfolios are constructed similarly. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Volatility returns are either model dependent, implied volatility returns (IV^r), or model-free, volatility swap rates returns (VSR^r). Straddle returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. In addition, the figure reports cumulative excess returns for a hedge fund relative volatility (RV) value index and CRSP value weighted index as benchmarks. The sample period is January 2006 - December 2015.

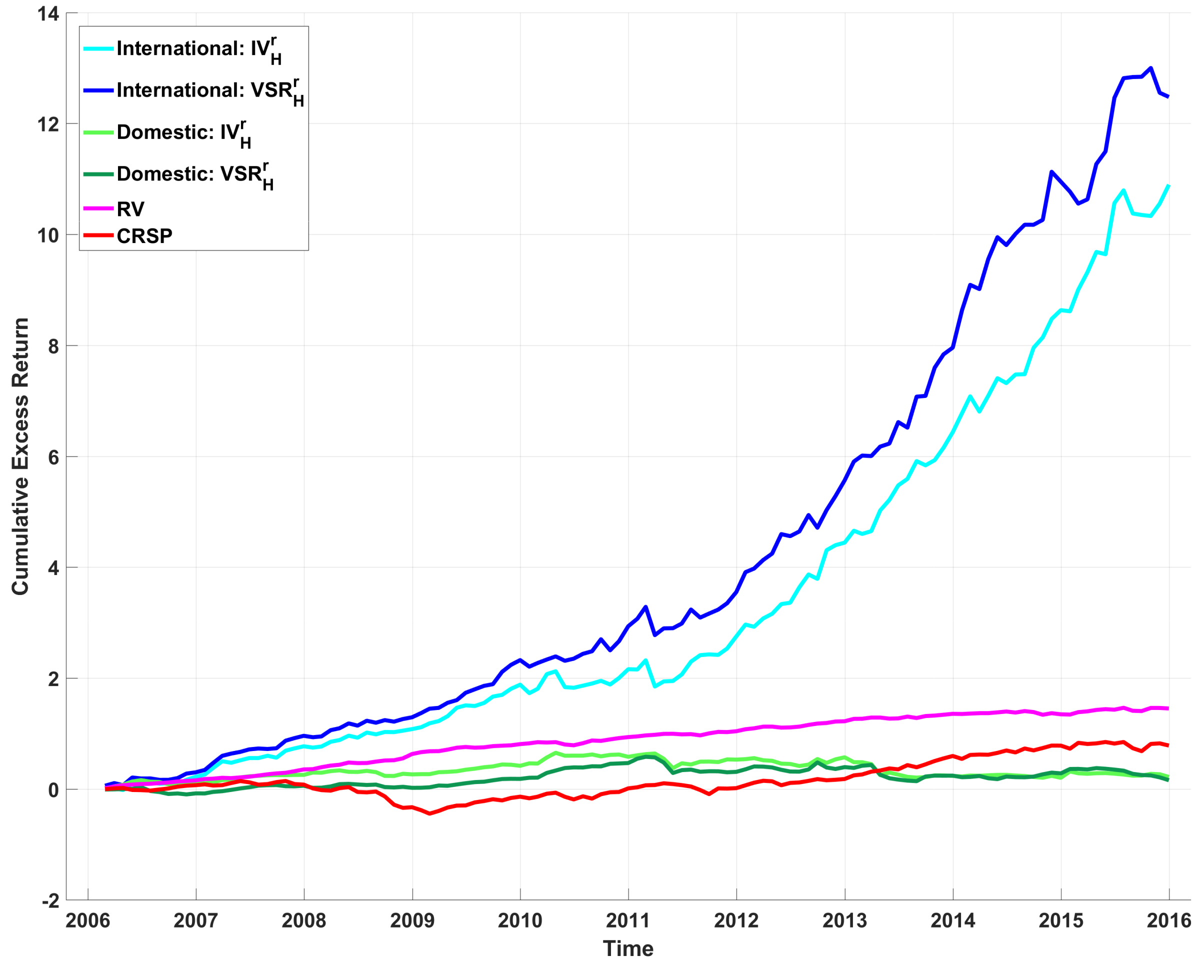

Figure 2.2

Cumulative Excess Returns of High Dispersion Trading International and Domestic Option Portfolios.

This figure shows cumulative excess returns of international and domestic high dispersion trading option strategies. Each month, international ETP and index dispersion pairs are ranked by previous day volatility returns difference and assigned to one of three equally weighted tercile portfolios. Then, ETP ATM straddles are sold and index ATM straddles are bought. The high (H) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. Domestic high dispersion trading portfolios are constructed similarly, by pairing domestic ETP and index straddles. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Volatility returns are either model dependent, implied volatility returns (IV^r), or model-free, volatility swap rates returns (VSR^r). Straddle returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. In addition, the figure reports cumulative excess returns for a hedge fund relative volatility (RV) value index and CRSP value weighted index as benchmarks. The sample period is January 2006 - December 2015.

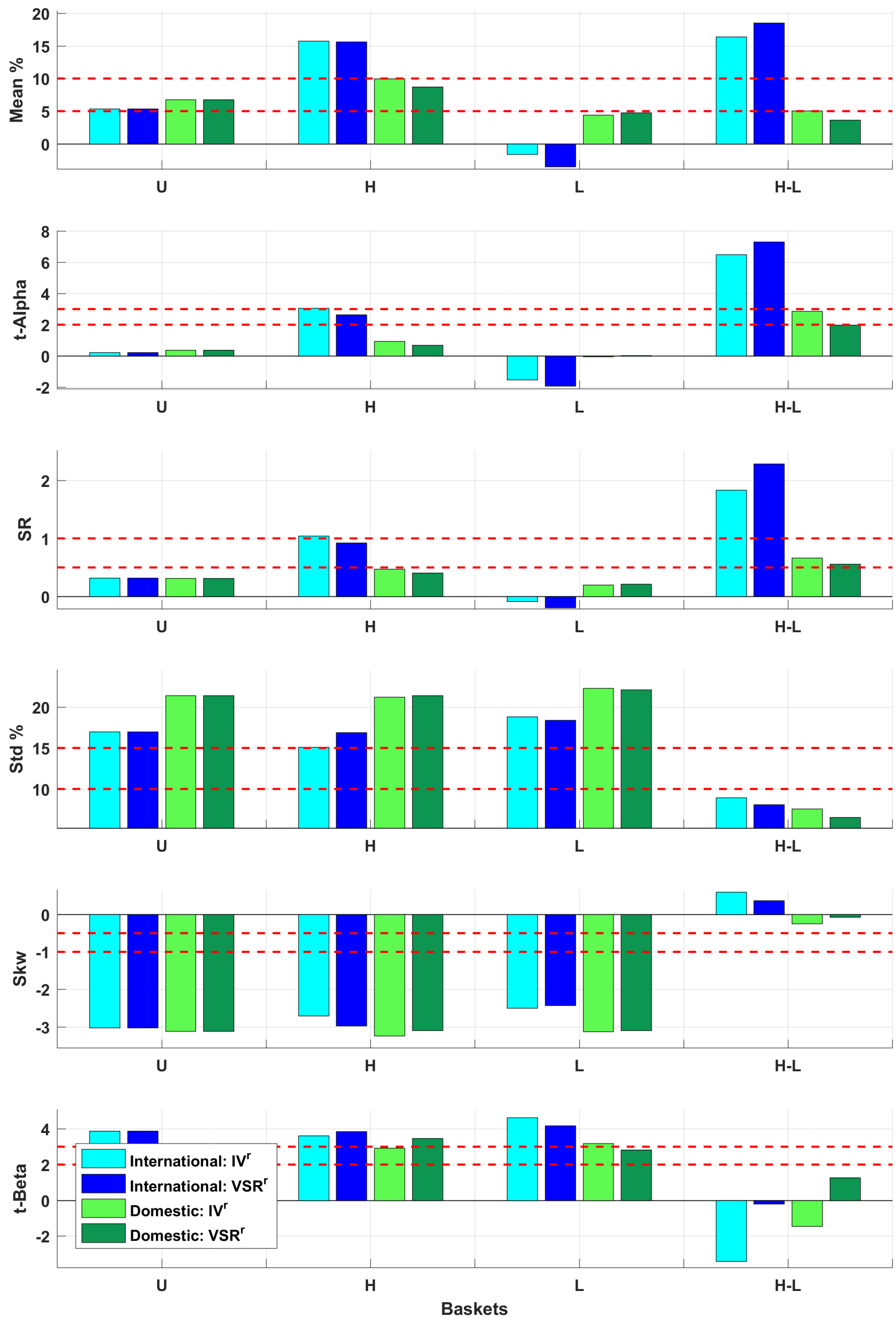

Figure 2.3
Cross-Section of International and Domestic Option Returns.

This figure shows statistical performance metrics for the cross-sections of international and domestic option returns. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddle portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

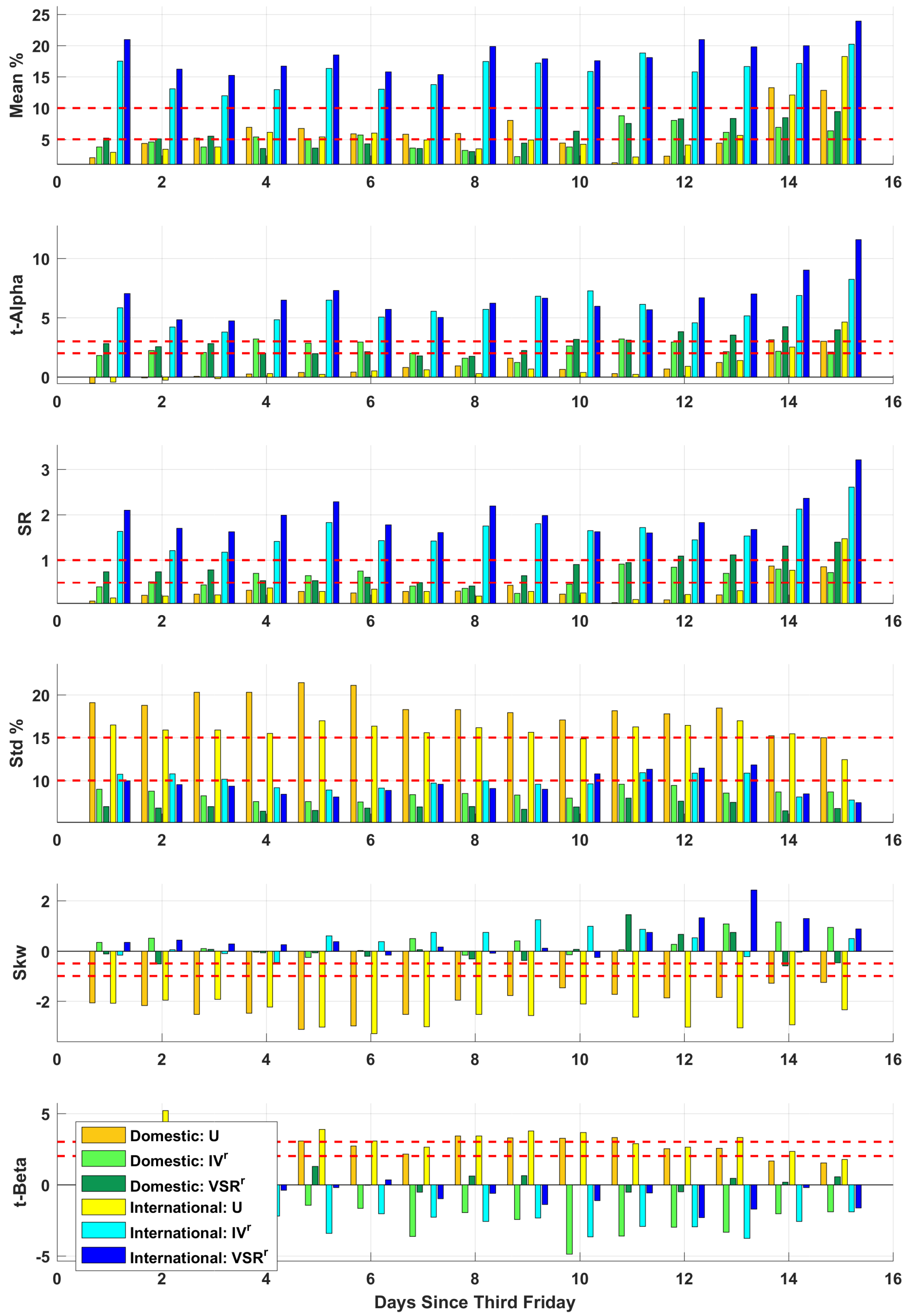

Figure 2.4
Cross-Section International and Domestic: Time Series Properties.

This figure investigates the time series properties of international and domestic option return cross-sections. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports short unconditional (U) and long-short straddle portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

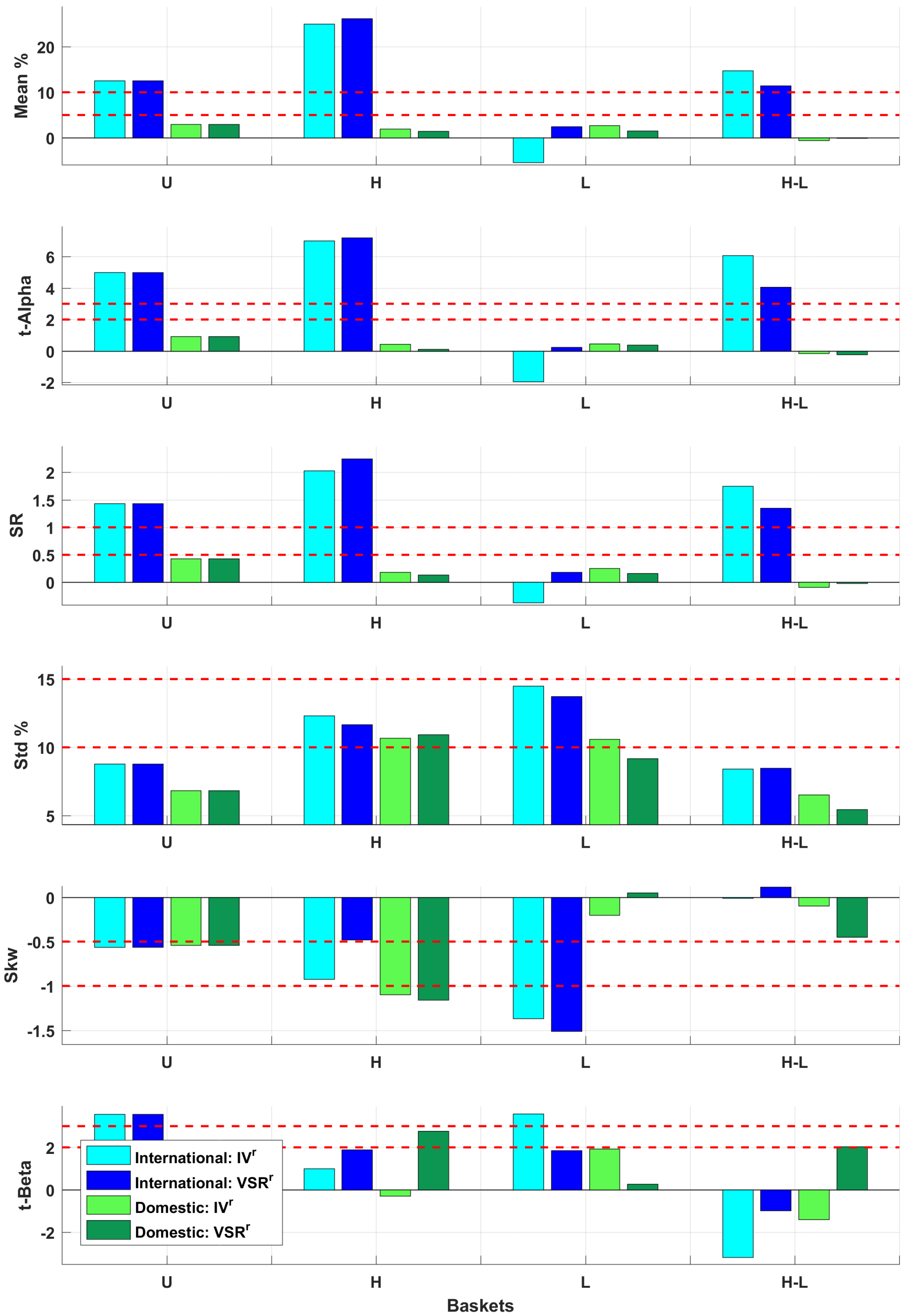

Figure 2.5
Dispersion Trading of International and Domestic Option Returns.

This figure shows statistical performance metrics for dispersion trading strategies of international and domestic option returns. Dispersion trading pairs are formed by selling ETP straddles and buying their corresponding index straddles. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) dispersion portfolios. The conditional pairs portfolios are sorted by previous day volatility returns ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

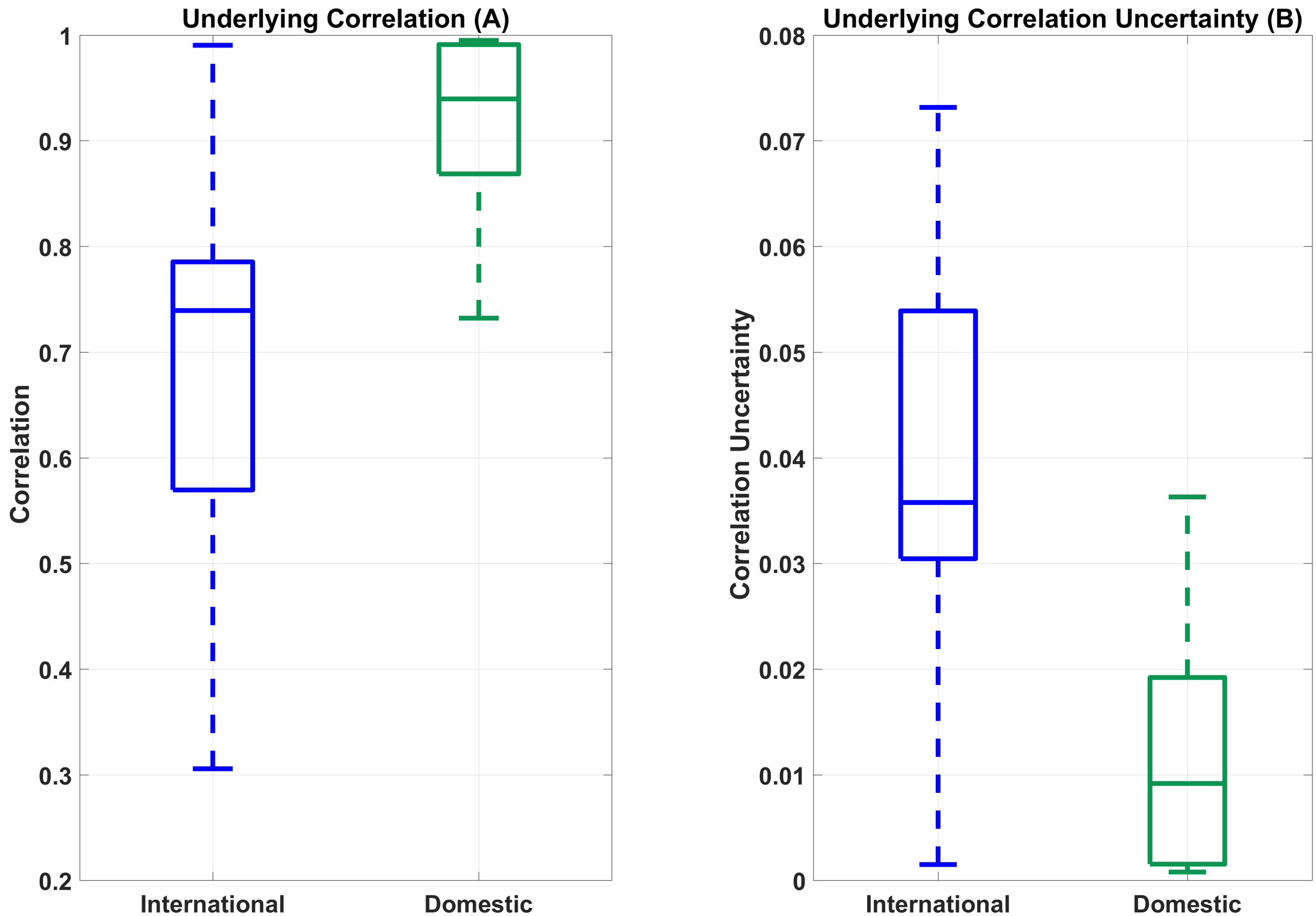

Figure 2.6
Underlying Correlation in International and Domestic Dispersion Pairs.

This figure shows the cross-sectional distribution of underlying correlations in international and domestic dispersion pairs. Panel (A) shows the distribution of correlations between ETP and index underlying assets. Panel (B) shows the distribution of the difference between the upper and lower bound of these estimated correlations at the 95% confidence level. The correlations are estimated by full-sample daily returns in USD between ETP and index underlying assets, for the period January 2006 - December 2015. In the plot, the central line indicates the median, while the bottom and top edges display the 25th and 75th percentiles. The dashed lines reach the most extreme data points.

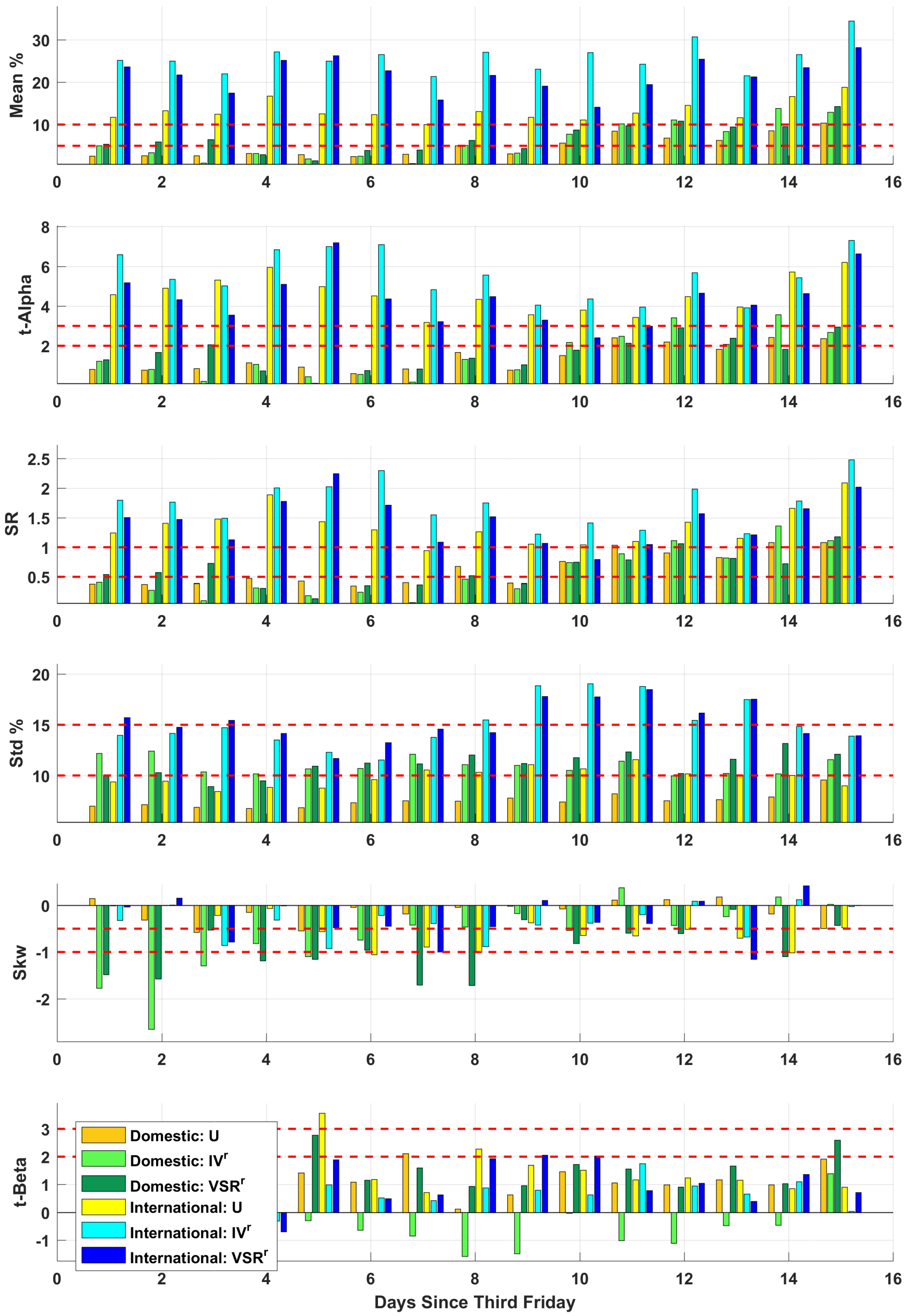

Figure 2.7
Dispersion Trading International and Domestic: Time Series Properties.

This figure investigates the time series properties of international and domestic dispersion trading option strategies. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and high dispersion trading portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r) ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

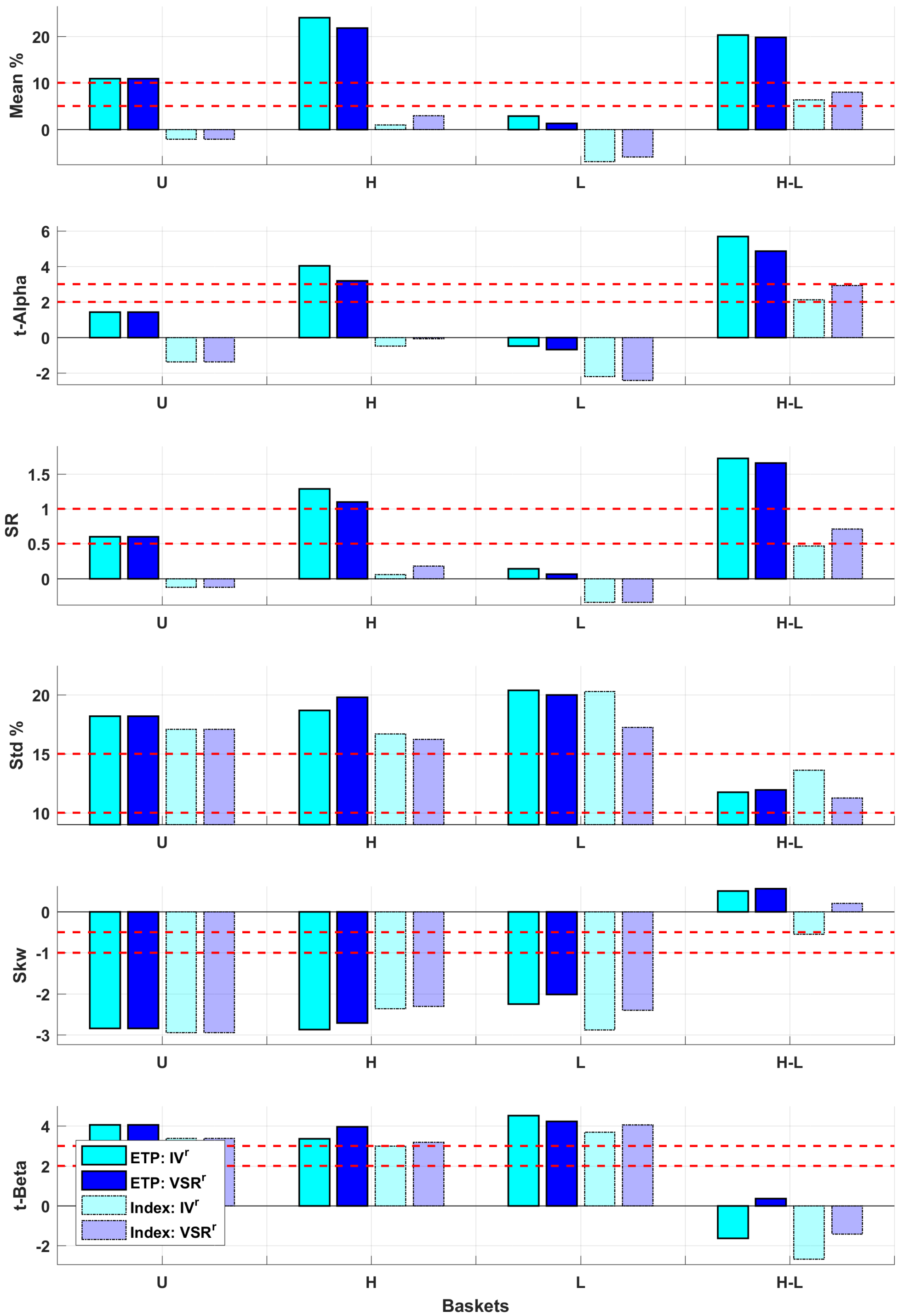

Figure 2.8
Cross-Section of International ETP and Index Option Returns.

This figure shows statistical performance metrics for the cross-sections of ETP and index option returns internationally. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddles portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

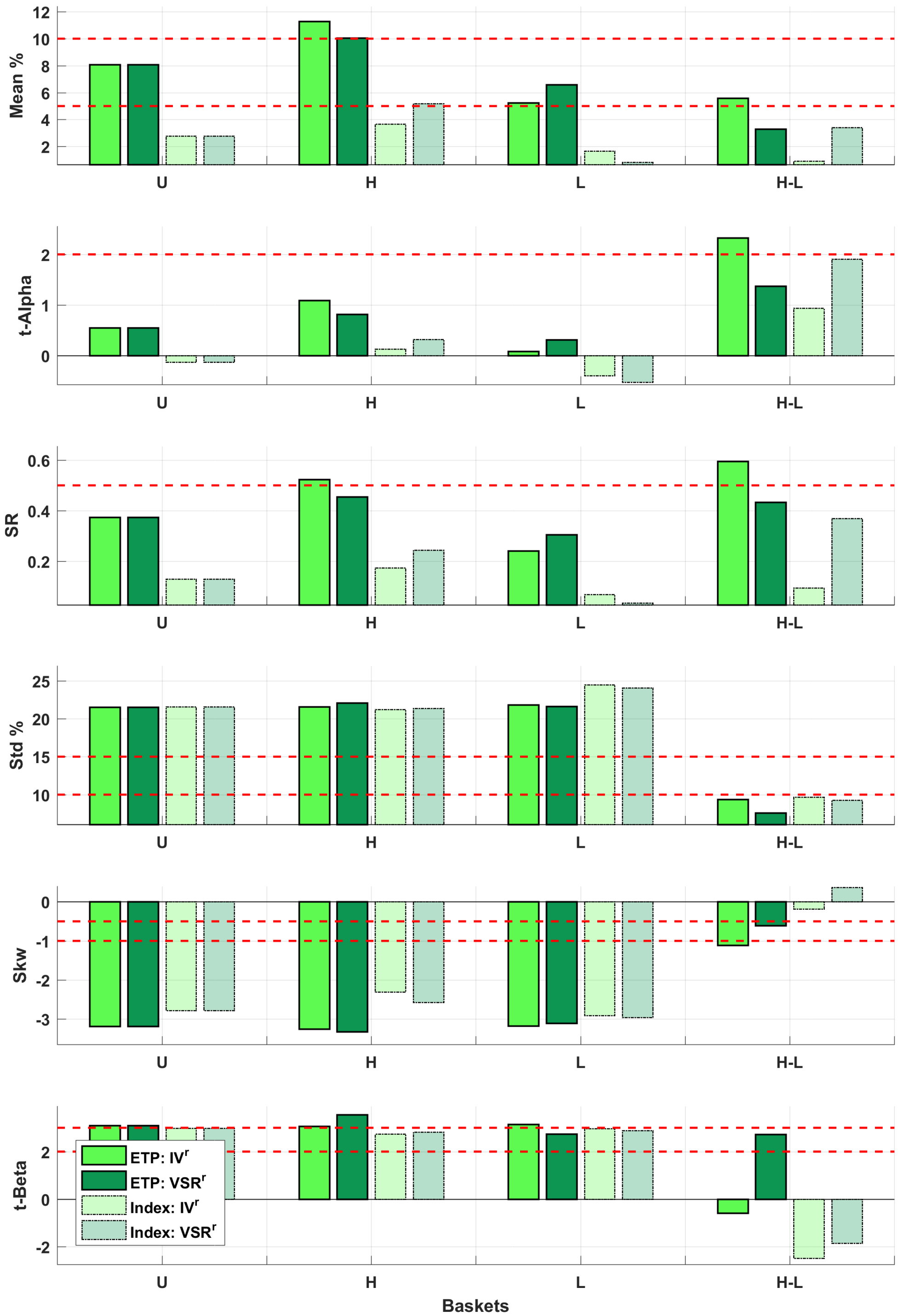

Figure 2.9
Cross-Section of Domestic ETP and Index Option Returns.

This figure shows statistical performance metrics for the cross-sections of ETP and index option returns domestically. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) straddles portfolios. U, H and L straddle returns are presented as short positions. The conditional portfolios are sorted by previous day volatility returns. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

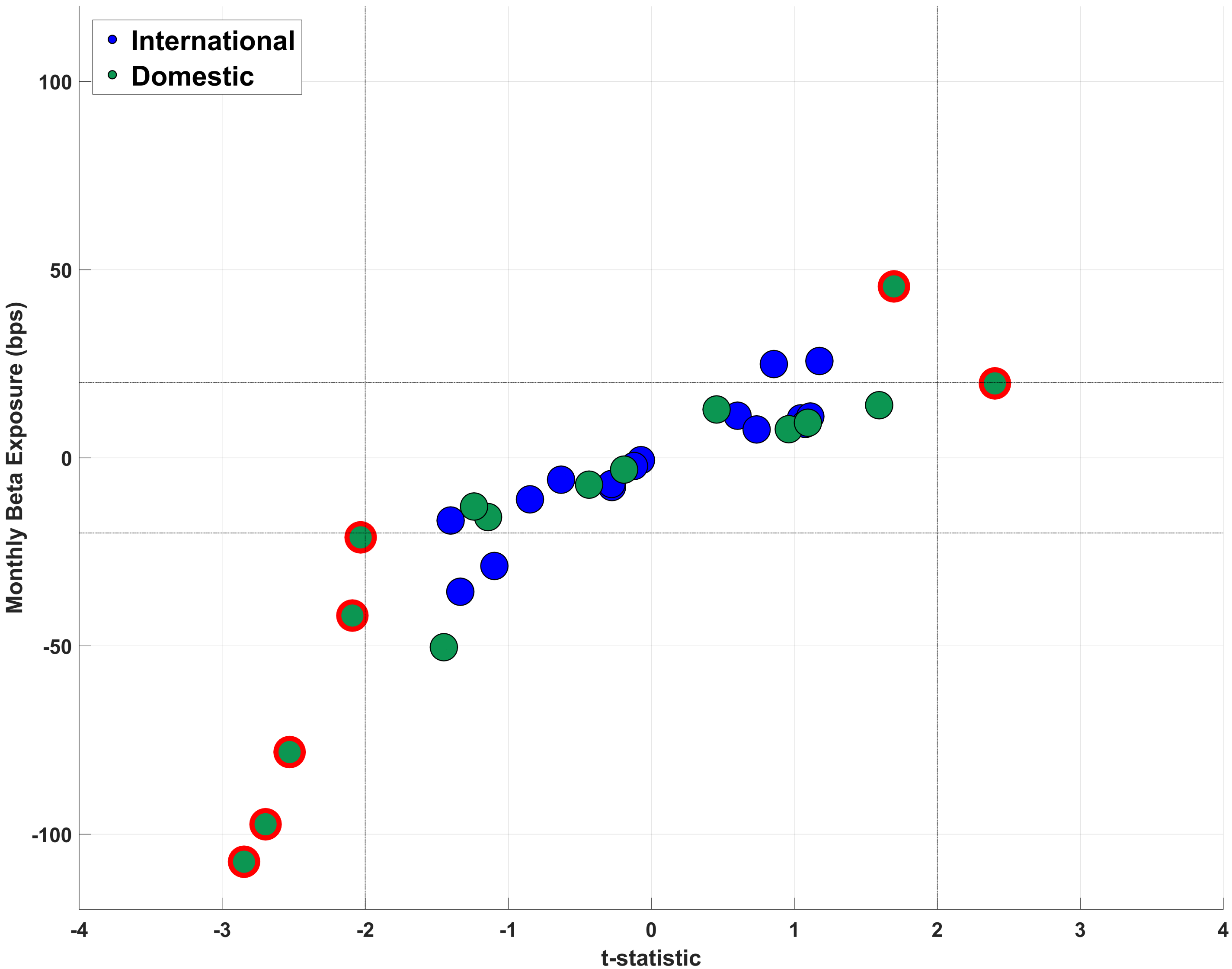

Figure 2.10
Volatility Hedge Funds' Exposures: International and Domestic.

This figure shows factor loadings of volatility hedge funds on international and domestic option strategies. The factor loadings are estimated by univariate time-series regressions of short volatility (SV) or relative value volatility (RV) funds index returns on a set of option strategies. The strategies considered are cross-sectional long-short option strategies among international and domestic derivatives, high dispersion trading strategies at the international and domestic level and cross-sectional long-short option strategies among ETP and index options in international and domestic markets. The x-axes represent the t-statistic of the estimation loading. The y-axes represent the monthly exposure in basis points for a one-standard-deviation increase in the explanatory variable. Red edges represent statistical significance at the 10% level with Newey and West (1987) standard errors (three lags). The sample period is January 2006 - December 2015.

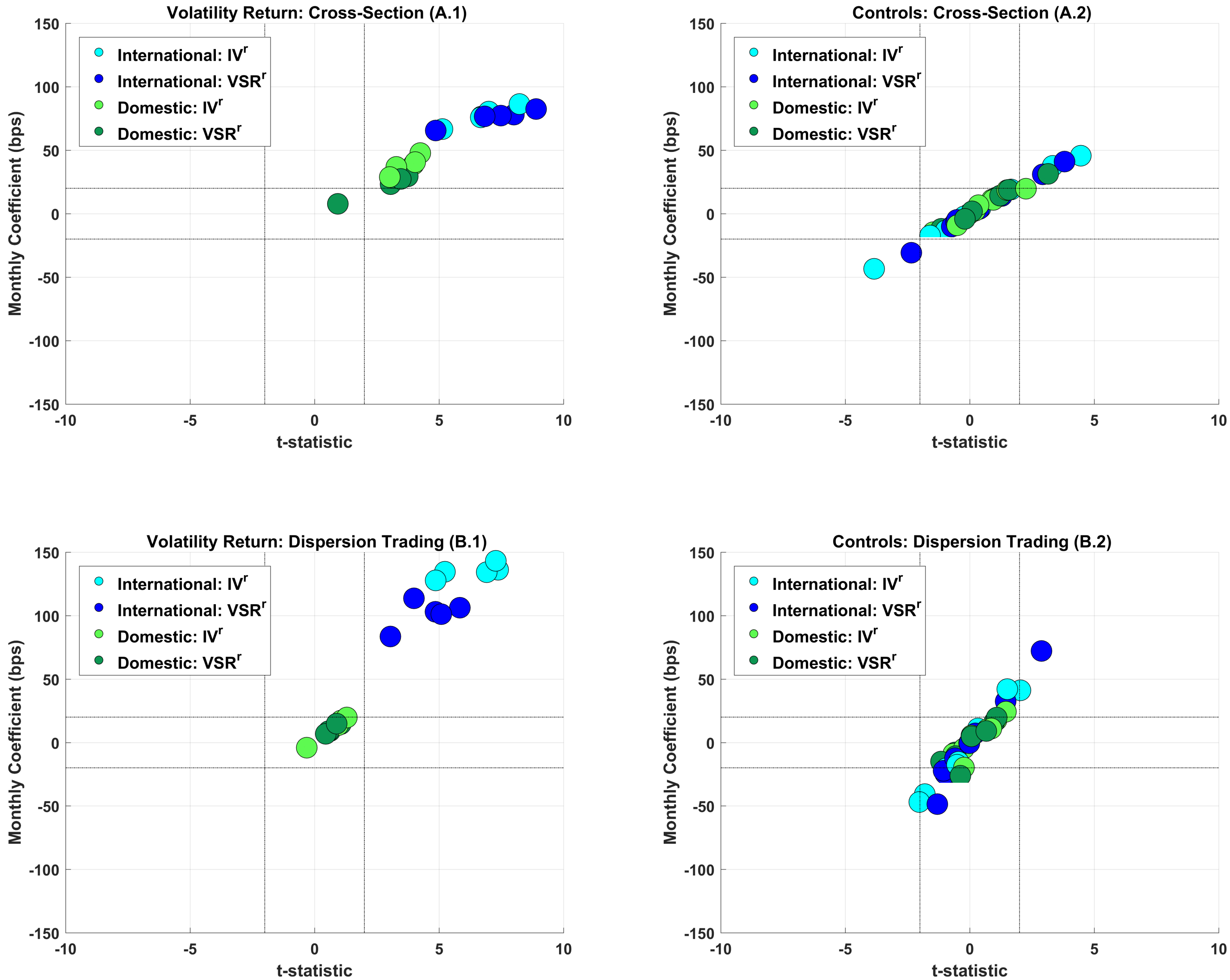

Figure 2.11
Fama-MacBeth Regressions of International and Domestic Option Returns.

This figure shows Fama and MacBeth (1973) regressions of international and domestic option returns. Each month, cross-sectional regressions of monthly option returns on portfolio formation volatility returns plus a set of control variables are estimated. The volatility return can be either model dependent (IV^r) or model-free (VSR^r) return. Panel (A.1) and (A.2) presents regression coefficients of international and domestic option returns cross-sections, for a detailed explanation see Table 2.10. While Panel (B.1) and (B.2) presents regression coefficients of dispersion trading option returns in international and domestic markets, for a detailed explanation see Table 2.11. Panel (A.1) and (B.1) shows the average coefficient of volatility returns as a function of their Newey and West (1987) t-statistic computed with three lags. While Panel (A.2) and (B.2) present the coefficients of the control variables as a function of their t-statistics. The color of control variables corresponds to the color of the corresponding main variable of interest. The sample period is January 2006 - December 2015.

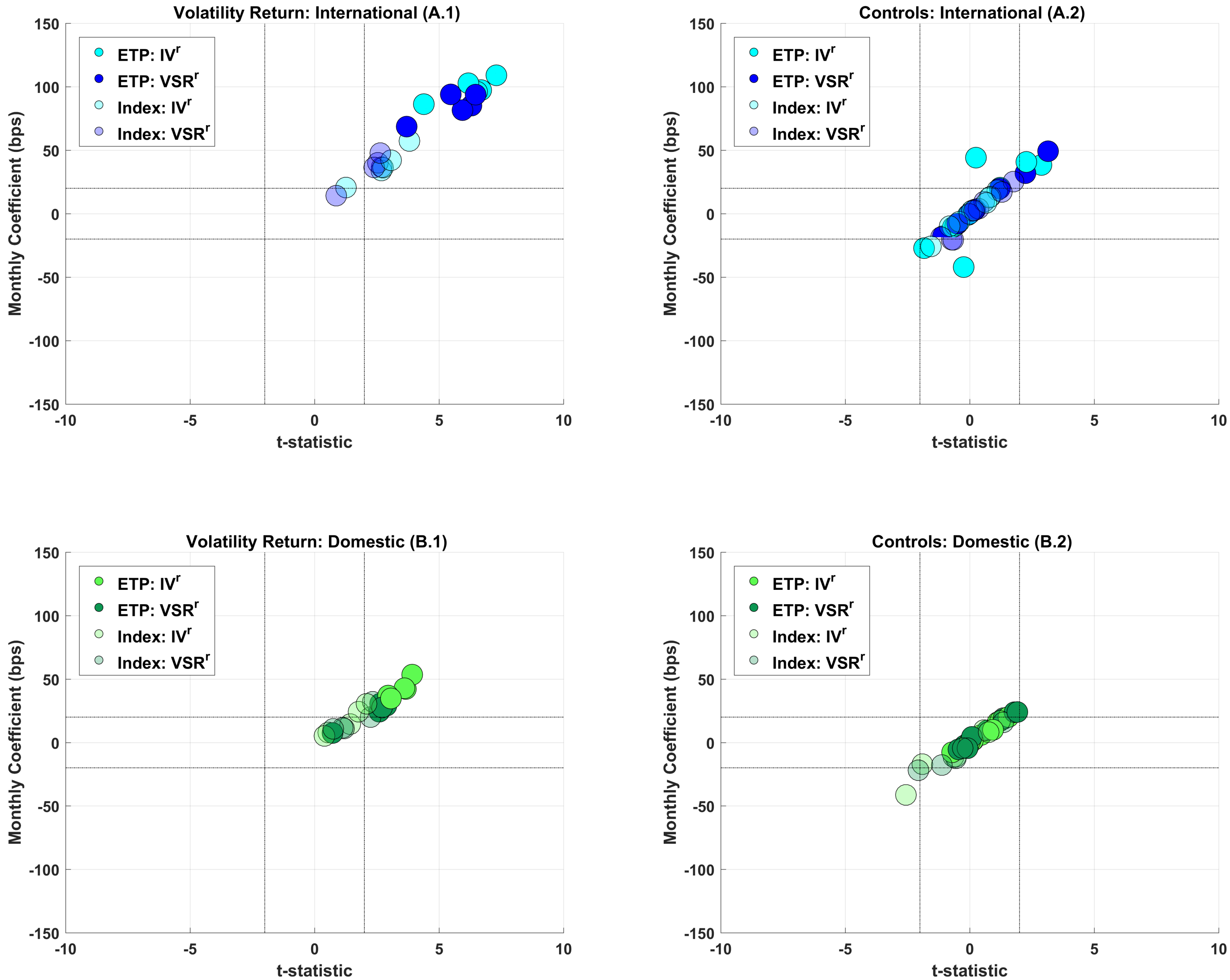

Figure 2.12
Fama-MacBeth Regressions of ETP and Index Option Returns.

This figure shows Fama and MacBeth (1973) regressions of ETP and index option returns cross-sections in international and domestic markets. Each month, cross-sectional regressions of monthly option returns on portfolio formation volatility returns plus a set of control variables are estimated. The volatility return can be either model dependent (IV^r) or model-free (VSR^r) return. Panel (A.1) and (A.2) presents regression coefficients of ETP and index option returns cross-sections at the international level, for a detailed explanation see Table 2.12. While Panel (B.1) and (B.2) presents regression coefficients of ETP and index option returns cross-sections at the domestic level, for a detailed explanation see Table 2.13. Panel (A.1) and (B.1) shows the coefficient of volatility returns as a function of their Newey and West (1987) t-statistic with three lags. While Panel (A.2) and (B.2) present the coefficients of the control variables as a function of their t-statistics. The color of control variables corresponds to the color of the corresponding main variable of interest. The sample period is January 2006 - December 2015.

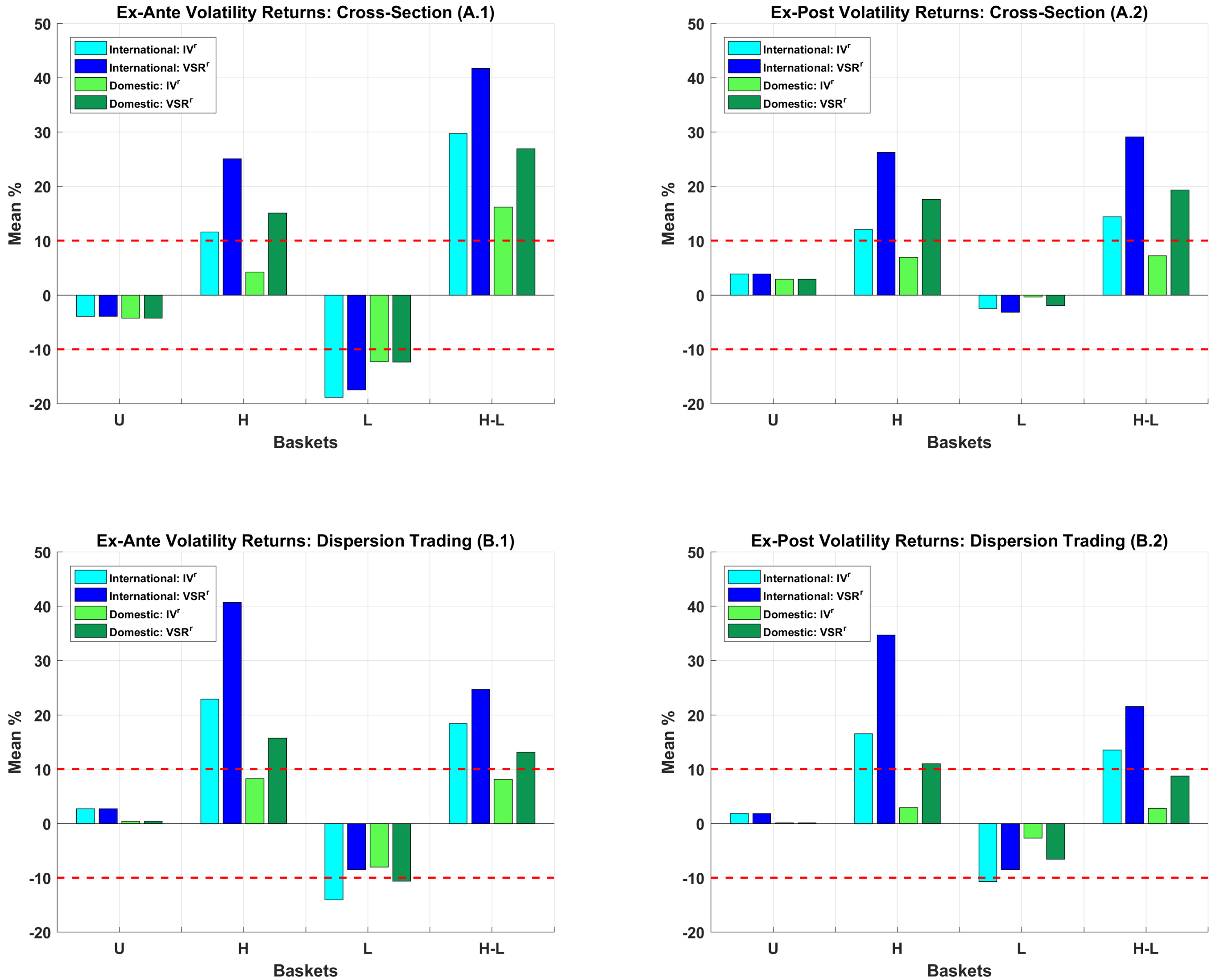

Figure 2.13
Ex-Ante and Ex-Post Volatility Returns of International and Domestic Portfolios.

This figure shows annualized average ex-ante and ex-post volatility returns for international and domestic option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Panel A.1 (A.2) shows ex-ante (ex-post) volatility returns for international and domestic cross-sections. Panel B.1 (B.2) reports ex-ante (ex-post) volatility returns for international and domestic dispersion trading strategies. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) volatility return portfolios. The conditional portfolios are sorted by previous day volatility returns. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

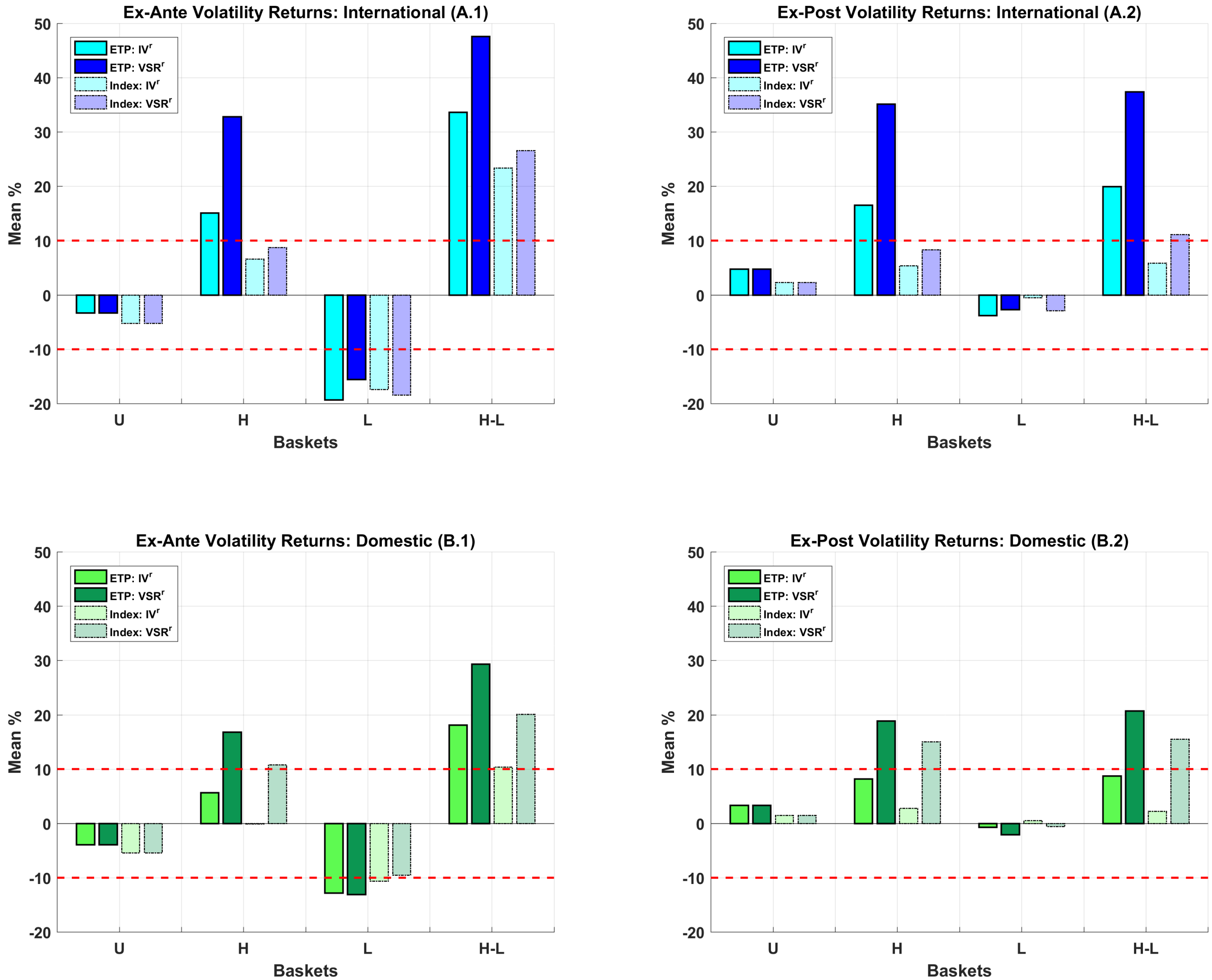

Figure 2.14

Ex-Ante and Ex-Post Volatility Returns of ETP and Index Portfolios.

This figure shows annualized average ex-ante and ex-post volatility returns for ETP and index option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Panel A.1 (A.2) shows ex-ante (ex-post) volatility returns for ETP and index cross-sections, internationally. Panel B.1 (B.2) reports ex-ante (ex-post) volatility returns for ETP and index cross-sections, domestically. The x-axes report unconditional (U), high (H) tercile, low (L) tercile and high minus low (H-L) volatility returns portfolios. The conditional portfolios are sorted by previous day volatility returns. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

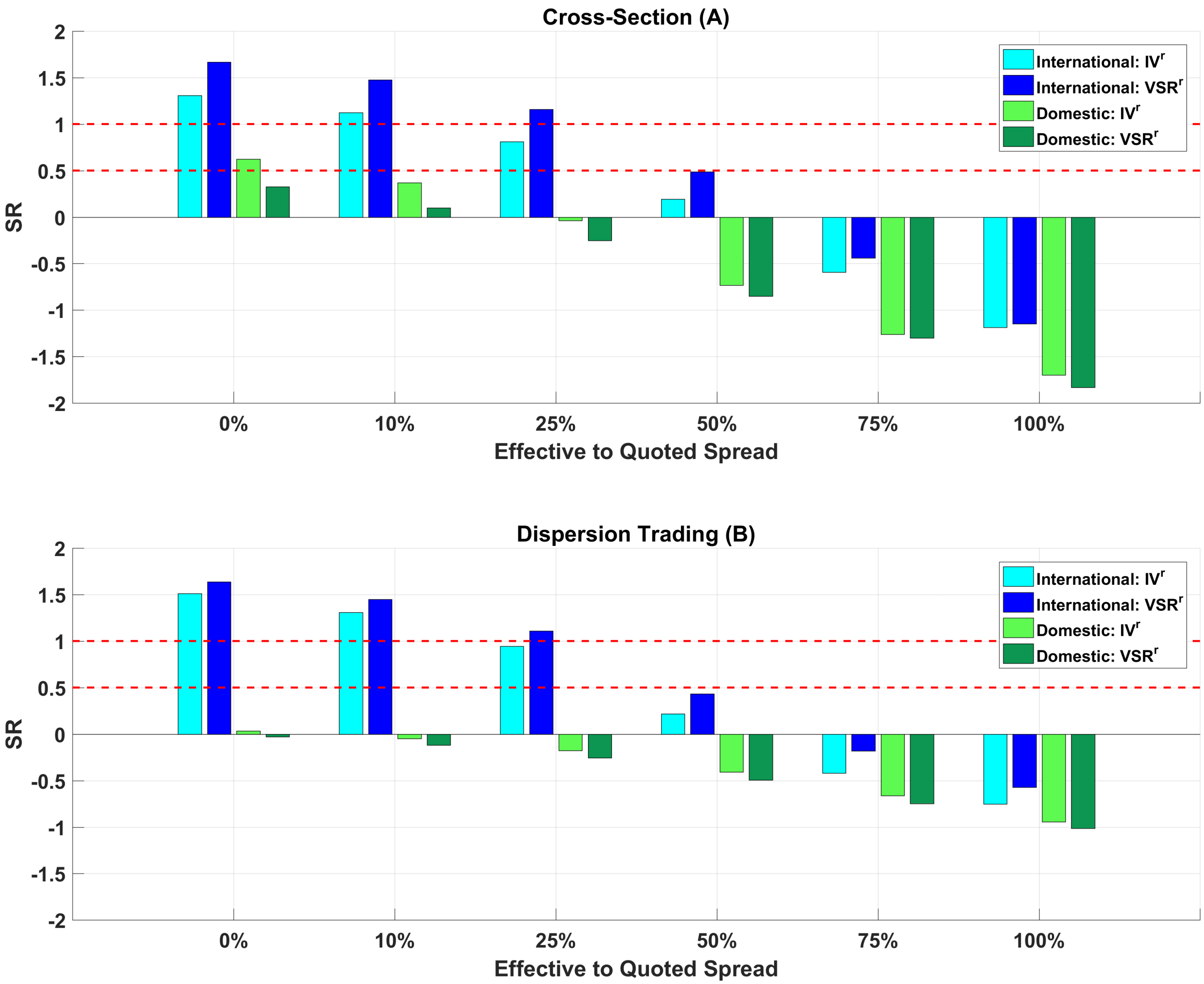

Figure 2.15
International and Domestic Option Strategies with Market Frictions.

This figure shows annualized Sharpe ratio (SR) of international and domestic option strategies. Option returns are computed by executing trades at x% of the effective to quoted bid-ask spread. Trades are executed on options with either positive volume or positive previous day open interest. The figure presents two types of option schemes, cross-sectional and dispersion trading strategies. Panel (A) shows international and domestic long-short option strategies in the cross-section. While Panel (B) shows international and domestic high dispersion trading option schemes. Sorts are either model dependent, implied volatility returns (IV^r), or model free, volatility swap rates returns (VSR^r). The sample period is January 2006 - December 2015.

Table 2.1
International and Domestic Option Strategies.

This table reports portfolio performance metrics for international and domestic option strategies. The sample period is January 2006 to December 2015. The table presents two types of option schemes, cross-sectional and dispersion trading strategies, and a set of benchmark indexes. Option returns are computed at mid-prices, denominated in US dollars, expressed in excess of US risk-free rate and held to maturity. The cross-sectional option schemes show portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table 2.7.1 (2.7.2). Ex-ante volatility returns are the sorting variable. There are two types of sorts: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility or volatility swap rate. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. The table includes high minus low (H-L) and unconditional (U) option portfolios. Unconditional portfolio is presented as short position. The dispersion trading option schemes show portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table 2.7.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference. Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs available at the moment of portfolio formation. The table includes high (H) and unconditional (U) dispersion trading portfolios. Panel (A) presents annualized average return (μ), annualized Sharpe ratio (SR), annualized risk-adjusted return (α) and its t-statistic (t-α). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), skewness (Skw), CAPM-β with respect to CRSP value weighted index (β) and its t-statistic (t-β). Panel (C) presents option portfolio volatility returns: ex-ante volatility return (ex-ante Vol. Ret.), its t-statistic, ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. Lastly, the benchmark indexes include: CRSP value weighted index, MSCI world index, a hedge fund short volatility (SV) index and a hedge fund relative volatility value (RV) index.

	Cross-Section						**Dispersion Trading**						**Benchmarks**			
	International			**Domestic**			**International**			**Domestic**						
Returns (A)	IV^r_{H-L}	VSR^r_{H-L}	U	IV^r_{H-L}	VSR^r_{H-L}	U	IV^r_{H}	VSR^r_{H}	U	IV^r_{H}	VSR^r_{H}	U	CRSP	MSCI	SV	RV
μ	16.38	18.52	5.39	5.04	3.64	6.76	24.97	26.23	12.59	1.98	1.48	2.94	5.83	3.93	7.79	9.04
SR	1.83	2.29	0.32	0.67	0.56	0.32	2.03	2.25	1.43	0.19	0.14	0.43	0.37	0.24	0.86	2.41
α	17.92	19.65	0.98	5.88	3.79	2.52	24.74	25.07	11.71	1.47	0.45	2.17	0.00	-2.07	5.46	8.47
t-α	6.49	7.29	0.23	2.86	1.98	0.39	7.00	7.19	4.99	0.45	0.12	0.94	0.76	-1.60	1.97	5.36
Risk (B)																
Std	8.93	8.10	16.97	7.56	6.54	21.41	12.32	11.68	8.78	10.67	10.93	6.83	15.69	16.70	9.07	3.76
Skw	0.60	0.37	-3.03	-0.25	-0.07	-3.12	-0.92	-0.48	-0.56	-1.10	-1.16	-0.54	-0.89	-1.00	-3.04	0.06
β	-0.16	-0.01	0.59	-0.08	0.05	0.65	0.07	0.10	0.18	-0.02	0.14	0.05	1.00	1.03	0.31	0.05
t-β	-3.41	-0.19	3.89	-1.45	1.28	3.07	0.99	1.89	3.57	-0.30	2.77	1.42		44.48	3.37	1.71
Volatility (C)																
ex-ante Vol. Ret.	29.74	41.70	-3.93	16.19	26.94	-4.27	22.89	40.70	2.74	8.25	15.70	0.38				
t-statistic	21.09	17.00	-1.08	15.02	16.84	-1.00	12.93	16.33	1.99	9.34	9.56	0.87				
ex-post Vol. Ret.	14.39	29.11	3.88	7.25	19.33	2.94	16.55	34.70	1.82	2.96	10.98	0.13				
t-statistic	13.88	13.84	1.63	9.37	19.08	1.02	8.03	13.26	1.21	3.32	10.59	0.27				

Table 2.2
Cross-Section of International and Domestic Option Returns.

This table reports portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table 2.7.1 (2.7.2). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	International							Domestic						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	5.39	15.76	-1.60	16.38	15.64	-3.50	18.52	6.76	9.95	4.43	5.04	8.75	4.78	3.64
t-μ	1.17	3.83	-0.31	5.82	3.54	-0.70	6.87	1.05	1.56	0.65	2.27	1.36	0.71	1.91
α	0.98	12.31	-6.89	17.92	11.71	-8.75	19.65	2.52	6.22	-0.21	5.88	4.41	0.29	3.79
t-α	0.23	3.07	-1.52	6.49	2.64	-1.91	7.29	0.39	0.94	-0.03	2.86	0.70	0.04	1.98
SR	0.32	1.04	-0.09	1.83	0.93	-0.19	2.29	0.32	0.47	0.20	0.67	0.41	0.22	0.56
Risk (B)														
Std	16.97	15.12	18.84	8.93	16.88	18.40	8.10	21.41	21.21	22.30	7.56	21.42	22.10	6.54
Kur	12.73	9.49	8.38	1.56	11.76	8.16	-0.00	12.96	13.48	13.39	0.99	12.37	13.65	0.89
Max	5.73	6.33	6.40	12.20	6.62	5.73	8.47	6.50	6.50	6.84	5.73	6.53	6.84	6.49
Min	-25.47	-20.43	-24.71	-5.96	-24.34	-23.67	-3.67	-30.89	-29.16	-32.67	-7.07	-29.71	-32.76	-5.94
Skw	-3.03	-2.71	-2.50	0.60	-2.98	-2.43	0.37	-3.12	-3.24	-3.13	-0.25	-3.10	-3.10	-0.07
Exposure (C)														
Δ	0.41	0.39	0.42	-0.03	0.37	0.42	-0.06	0.43	0.42	0.43	-0.00	0.41	0.44	-0.03
Γ	0.13	0.15	0.13	0.03	0.21	0.09	0.12	0.12	0.12	0.13	-0.01	0.15	0.11	0.05
β	0.59	0.46	0.66	-0.16	0.58	0.61	-0.01	0.65	0.61	0.70	-0.08	0.69	0.64	0.05
t-β	3.89	3.63	4.62	-3.41	3.86	4.18	-0.19	3.07	2.94	3.19	-1.45	3.47	2.83	1.28
ρ	-13.39	-11.86	-12.89	-3.40	-14.24	-11.17	7.80	-5.72	-5.06	-6.32	-10.33	-6.95	-3.86	0.62

Table 2.3

Alpha and Factor Exposures of Cross-Sectional Long-Short International and Domestic Option Portfolios.

This table reports time series regressions for international and domestic cross-sectional long-short option strategies. The dependent variable is an international or domestic long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 2.2 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										**Domestic**									
	IV^r_{H-L}					VSR^r_{H-L}					IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	17.919***	17.105***	17.337***	16.362***	18.702***	19.646***	19.465***	19.860***	19.321***	19.594***	5.878***	5.451**	5.493**	6.886***	7.280**	3.787**	3.944**	4.154**	4.984**	2.592
	(6.493)	(6.196)	(6.234)	(5.767)	(5.126)	(7.293)	(7.188)	(7.457)	(7.301)	(6.058)	(2.859)	(2.391)	(2.491)	(3.124)	(1.985)	(1.984)	(2.301)	(2.207)	(2.452)	(1.007)
MKT_D	-0.854***					-0.120					-0.494*					0.052				
	(-3.486)					(-0.455)					(-1.770)					(0.259)				
SMB_D	-0.072					-0.335*					0.044		-0.053	-0.004	-0.075	0.221		0.282	0.300	0.222
	(-0.348)					(-1.676)					(0.192)		(-0.227)	(-0.016)	(-0.332)	(1.042)		(1.291)	(1.429)	(1.030)
HML_D	0.046					0.486**					0.691**		0.650**	0.476	0.600*	0.250		0.240	0.129	0.291
	(0.189)					(2.260)					(2.439)		(2.101)	(1.562)	(1.892)	(1.208)		(1.119)	(0.560)	(1.429)
RMW_D	-0.547**					-0.423*					0.113		0.234	0.169	0.244	0.026		-0.012	-0.048	0.018
	(-2.381)					(-1.768)					(0.570)		(1.080)	(0.833)	(1.067)	(0.110)		(-0.051)	(-0.226)	(0.082)
CMA_D	0.103					-0.173					-0.045		-0.053	-0.067	-0.017	-0.111		-0.121	-0.128	-0.127
	(0.443)					(-0.837)					(-0.212)		(-0.240)	(-0.345)	(-0.081)	(-0.576)		(-0.622)	(-0.709)	(-0.684)
MOM_D	0.461***					0.512**					0.225		0.273	0.173	0.200	0.039		0.036	-0.031	0.077
	(2.667)					(2.472)					(0.957)		(1.223)	(0.740)	(0.771)	(0.214)		(0.201)	(-0.160)	(0.413)
MKT_I		-0.699**					-0.144					-0.690**					0.081			
		(-2.455)					(-0.617)					(-2.147)					(0.327)			
SMB_I		-0.016	-0.084	0.025	0.020		-0.263	-0.306	-0.255	-0.254		0.161					0.361**			
		(-0.071)	(-0.403)	(0.115)	(0.088)		(-1.211)	(-1.446)	(-1.200)	(-1.200)		(1.141)					(2.412)			
HML_I		0.160	-0.128	-0.160	-0.168		0.361	0.307	0.294	0.294		1.101***					0.453*			
		(0.525)	(-0.538)	(-0.662)	(-0.738)		(1.486)	(1.359)	(1.311)	(1.308)		(3.681)					(1.853)			
RMW_I		-0.266	-0.274	-0.133	-0.153		-0.559**	-0.596**	-0.532**	-0.533**		0.173					-0.033			
		(-1.021)	(-1.163)	(-0.486)	(-0.564)		(-2.257)	(-2.469)	(-2.241)	(-2.243)		(0.789)					(-0.165)			
CMA_I		-0.022	0.170	0.423*	0.491**		-0.151	-0.182	-0.060	-0.046		-0.466					-0.087			
		(-0.065)	(0.714)	(1.680)	(2.026)		(-0.589)	(-0.842)	(-0.282)	(-0.207)		(-1.429)					(-0.265)			
MOM_I		0.497**	0.526***	0.421**	0.378*		0.523**	0.551**	0.507**	0.501**		0.280					0.074			
		(2.429)	(2.719)	(2.113)	(1.745)		(2.238)	(2.492)	(2.263)	(2.187)		(1.153)					(0.340)			
U			-0.829***					-0.355*					-0.249					-0.246		
			(-3.175)					(-1.771)					(-0.802)					(-1.127)		
SV				-0.156					-0.035					-0.568**					-0.377*	
				(-0.544)					(-0.240)					(-2.228)					(-1.820)	
RV					-0.341					-0.047					-0.257					0.156
					(-1.295)					(-0.264)					(-0.906)					(1.016)
$\bar{R}^2$	7.655	6.015	11.791	2.664	4.116	1.340	3.732	5.648	3.560	3.582	3.769	10.063	1.471	6.475	1.549	-1.164	4.721	0.469	2.500	-0.541
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 2.4

Dispersion Trading of International and Domestic Option Returns.

This table reports portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table 2.7.3 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference, equation (2.2). Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. Options are held to maturity. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The dispersion trading volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) dispersion trading portfolio is the equally weighted average of the ETP minus index straddles pairs. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) dispersion portfolios. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	International							Domestic						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	12.59	24.97	-5.39	14.73	26.23	2.50	11.48	2.94	1.98	2.72	-0.58	1.48	1.52	-0.08
t-μ	5.15	7.61	-1.32	5.92	7.97	0.61	4.54	1.23	0.59	0.79	-0.30	0.38	0.53	-0.05
α	11.71	24.74	-7.57	15.62	25.07	1.07	11.51	2.17	1.47	1.55	-0.27	0.45	1.09	-0.38
t-α	4.99	7.00	-1.95	6.08	7.19	0.25	4.06	0.94	0.45	0.47	-0.15	0.12	0.38	-0.23
SR	1.43	2.03	-0.37	1.75	2.25	0.18	1.35	0.43	0.19	0.26	-0.09	0.14	0.17	-0.01
Risk (B)														
Std	8.78	12.32	14.50	8.42	11.68	13.72	8.49	6.83	10.67	10.61	6.54	10.93	9.18	5.44
Kur	1.24	4.81	3.63	2.55	2.44	5.13	1.17	1.59	5.38	0.58	0.72	4.76	1.25	0.71
Max	8.26	12.86	9.16	9.48	12.86	9.16	8.44	5.37	9.56	8.46	5.10	9.41	9.46	3.38
Min	-7.14	-14.22	-17.26	-8.21	-11.89	-17.73	-7.05	-7.22	-13.69	-9.51	-5.83	-12.72	-7.93	-5.47
Skw	-0.56	-0.92	-1.37	-0.01	-0.48	-1.51	0.11	-0.54	-1.10	-0.20	-0.10	-1.16	0.05	-0.45
Exposure (C)														
Δ	-0.10	-0.12	-0.08	-0.02	-0.13	-0.07	-0.03	-0.06	-0.07	-0.07	-0.00	-0.08	-0.05	-0.01
Γ	0.25	0.27	0.24	0.02	0.31	0.20	0.05	0.18	0.20	0.20	-0.00	0.22	0.17	0.02
β	0.18	0.07	0.36	-0.14	0.10	0.27	-0.07	0.05	-0.02	0.13	-0.07	0.14	0.01	0.06
t-β	3.57	0.99	3.59	-3.19	1.89	1.86	-0.98	1.42	-0.30	1.94	-1.41	2.77	0.27	2.04
ρ	-13.73	-11.50	-5.80	-1.93	-14.77	-8.19	-7.73	10.24	-7.02	-2.29	-11.25	18.33	-5.23	2.00

Table 2.5

Alpha and Factor Exposures of Dispersion Trading International and Domestic Option Portfolios.

This table reports time series regressions for international and domestic high dispersion trading option strategies. The dependent variable is an international or domestic high dispersion trading option portfolio sorted either by IV returns or VSR returns. The high dispersion trading option returns correspond to those in Table 2.4 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										Domestic									
	IV^r_H					VSR^r_H					IV^r_H					VSR^r_H				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	24.740***	24.725***	12.111***	25.070***	23.647***	25.072***	25.553***	15.184***	25.423***	24.767***	1.473	2.423	-1.281	0.707	-0.362	0.447	2.760	-1.960	0.038	-1.368
	(7.000)	(6.706)	(3.412)	(6.791)	(4.697)	(7.193)	(7.264)	(4.330)	(7.264)	(5.970)	(0.446)	(0.962)	(-0.551)	(0.211)	(-0.097)	(0.122)	(0.803)	(-0.978)	(0.010)	(-0.250)
MKT_D	0.406					0.692**					-0.019					0.577**				
	(1.047)					(2.162)					(-0.057)					(2.160)				
SMB_D	-0.671**					-0.424					0.204		-0.088	0.156	0.177	0.496		0.327*	0.595	0.633*
	(-2.044)					(-1.192)					(0.573)		(-0.446)	(0.424)	(0.515)	(1.297)		(1.723)	(1.642)	(1.771)
HML_D	-0.111					-0.238					0.255		0.619*	0.336	0.309	-0.419		0.042	-0.253	-0.308
	(-0.323)					(-0.711)					(0.572)		(1.889)	(0.981)	(0.682)	(-1.332)		(0.199)	(-0.802)	(-0.800)
RMW_D	-0.437					-0.070					0.610		0.618**	0.654	0.627	0.163		-0.004	0.057	0.010
	(-1.359)					(-0.184)					(1.472)		(2.319)	(1.635)	(1.532)	(0.356)		(-0.017)	(0.122)	(0.023)
CMA_D	0.170					0.333					-0.049		-0.295	-0.038	-0.071	-0.017		-0.309*	-0.002	-0.052
	(0.582)					(1.084)					(-0.152)		(-1.297)	(-0.115)	(-0.223)	(-0.058)		(-1.668)	(-0.008)	(-0.173)
MOM_D	-0.174					-0.154					-0.194		0.092	-0.149	-0.130	-0.167		0.113	-0.151	-0.132
	(-0.448)					(-0.507)					(-0.660)		(0.366)	(-0.503)	(-0.445)	(-0.599)		(0.602)	(-0.541)	(-0.459)
MKT_I		0.283					0.589					-0.459					0.384			
		(0.641)					(1.494)					(-1.083)					(1.088)			
SMB_I		-0.272	-0.310	-0.290	-0.283		-0.024	-0.087	-0.033	-0.059		0.163					0.250			
		(-0.917)	(-1.580)	(-0.970)	(-0.902)		(-0.083)	(-0.470)	(-0.110)	(-0.194)		(0.840)					(1.257)			
HML_I		0.073	-0.103	0.202	0.208		0.027	0.027	0.303	0.300		1.183**					-0.070			
		(0.150)	(-0.325)	(0.353)	(0.365)		(0.067)	(0.083)	(0.874)	(0.887)		(2.429)					(-0.174)			
RMW_I		0.007	0.147	-0.048	-0.033		-0.009	0.037	-0.094	-0.112		0.404					-0.411			
		(0.020)	(0.510)	(-0.132)	(-0.088)		(-0.028)	(0.133)	(-0.263)	(-0.301)		(1.014)					(-1.046)			
CMA_I		-0.070	0.421*	-0.255	-0.278		0.273	0.453	-0.018	-0.158		-0.890					-0.251			
		(-0.197)	(1.915)	(-0.809)	(-0.802)		(0.713)	(1.556)	(-0.060)	(-0.539)		(-1.601)					(-0.564)			
MOM_I		-0.190	-0.223	-0.159	-0.135		-0.180	-0.173	-0.114	-0.088		0.151					0.024			
		(-0.453)	(-0.776)	(-0.363)	(-0.291)		(-0.515)	(-0.552)	(-0.323)	(-0.242)		(0.527)					(0.074)			
U			2.374***					2.074***					2.171***					2.552***		
			(8.252)					(6.861)					(6.677)					(9.145)		
SV				0.052					0.330					0.248					0.406**	
				(0.190)					(1.447)					(0.773)					(2.137)	
RV					0.188					0.222					0.223					0.323
					(0.531)					(0.975)					(1.059)					(1.067)
$\bar{R}^2$	-1.394	-3.319	39.285	-3.617	-3.351	-0.983	-2.039	32.867	-2.726	-3.121	-2.679	3.329	48.017	-2.077	-2.164	1.817	2.050	66.289	1.004	0.498
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 2.6
Cross-Section of International ETP and Index Option Returns.

This table reports portfolio performance metrics for the cross-sections of ETP and index option returns internationally. The ETP (index) cross-section includes all ETP (index) option products displayed in Table 2.7.1 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	10.93	24.09	2.85	20.30	21.80	1.25	19.83	-2.15	1.00	-6.92	6.36	2.91	-5.91	8.01
t-μ	2.29	5.15	0.52	5.69	4.28	0.23	5.42	-0.45	0.22	-1.20	1.71	0.68	-1.21	2.44
α	6.34	19.98	-2.33	21.15	16.99	-3.53	19.69	-6.44	-2.15	-12.25	8.17	-0.24	-10.56	9.29
t-α	1.43	4.05	-0.48	5.69	3.20	-0.67	4.86	-1.37	-0.48	-2.20	2.14	-0.06	-2.42	2.93
SR	0.60	1.29	0.14	1.72	1.10	0.06	1.66	-0.13	0.06	-0.34	0.47	0.18	-0.34	0.71
Risk (B)														
Std	18.22	18.70	20.41	11.77	19.83	20.01	11.97	17.08	16.71	20.32	13.63	16.24	17.25	11.26
Kur	10.13	9.74	6.20	2.21	8.62	5.14	0.55	13.11	8.21	12.27	3.67	8.06	8.49	2.09
Max	6.19	7.03	6.90	15.84	7.02	7.03	12.53	5.63	6.17	6.24	15.51	6.39	5.80	14.67
Min	-24.39	-22.80	-22.94	-8.36	-24.39	-23.50	-5.06	-26.82	-22.59	-30.58	-15.55	-22.70	-23.47	-8.43
Skw	-2.84	-2.86	-2.24	0.51	-2.70	-2.01	0.57	-2.94	-2.36	-2.88	-0.54	-2.31	-2.40	0.21
Exposure (C)														
Δ	0.37	0.34	0.39	-0.05	0.32	0.41	-0.09	0.45	0.45	0.45	0.01	0.46	0.44	0.02
Γ	0.22	0.25	0.21	0.04	0.30	0.18	0.12	0.01	0.01	0.01	-0.00	0.01	0.01	-0.00
β	0.61	0.51	0.65	-0.11	0.61	0.59	0.03	0.56	0.44	0.69	-0.20	0.46	0.57	-0.09
t-β	4.07	3.36	4.54	-1.63	3.97	4.25	0.37	3.38	3.01	3.69	-2.66	3.19	4.06	-1.42
ρ	-15.64	-18.93	-11.38	-5.29	-16.46	-8.21	2.34	-10.95	-8.71	-10.88	-11.79	-13.60	-9.80	-8.81

Table 2.7

Alpha and Factor Exposures of Cross-Sectional Long-Short International ETP and Index Portfolios.

This table reports time series regressions for ETP and index cross-sectional long-short option strategies internationally. The dependent variable is an ETP or index long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 2.6 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										Index									
	IV^r_{H-L}					VSR^r_{H-L}					IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	21.154***	20.176***	20.748***	18.856***	22.212***	19.690***	19.026***	19.718***	17.828***	17.159***	8.167**	7.866**	5.625	6.738*	7.122	9.292***	8.071**	7.068**	6.375*	3.604
	(5.691)	(5.271)	(4.886)	(4.887)	(3.667)	(4.861)	(4.632)	(4.778)	(4.298)	(3.409)	(2.141)	(2.084)	(1.642)	(1.692)	(1.542)	(2.933)	(2.341)	(2.178)	(1.852)	(0.789)
MKT_D	-0.549					0.292					-1.046**					-0.410				
	(-1.340)					(0.605)					(-2.473)					(-1.087)				
SMB_D	-0.239					-0.675*					-0.070					0.032				
	(-0.781)					(-1.946)					(-0.167)					(0.080)				
HML_D	0.121					0.377					0.111					0.725**				
	(0.411)					(1.067)					(0.287)					(2.114)				
RMW_D	-0.311					-0.058					-0.277					0.047				
	(-1.021)					(-0.155)					(-0.732)					(0.137)				
CMA_D	0.185					0.065					-0.247					-0.310				
	(0.560)					(0.188)					(-0.882)					(-0.984)				
MOM_D	0.210					-0.062					0.249					0.889**				
	(0.675)					(-0.167)					(0.543)					(2.035)				
MKT_I		-0.366					0.314					-1.255***					-0.531			
		(-0.815)					(0.620)					(-2.755)					(-1.311)			
SMB_I		-0.047	-0.087	0.006	-0.038		-0.305	-0.338	-0.272	-0.312		-0.318	-0.311	-0.252	-0.223		-0.203	-0.164	-0.134	-0.128
		(-0.176)	(-0.342)	(0.023)	(-0.140)		(-1.034)	(-1.173)	(-0.953)	(-1.087)		(-0.965)	(-0.942)	(-0.756)	(-0.662)		(-0.698)	(-0.565)	(-0.468)	(-0.446)
HML_I		0.065	-0.094	-0.095	-0.113		0.175	0.317	0.332	0.328		0.294	-0.229	-0.282	-0.279		0.703*	0.466	0.469	0.479
		(0.177)	(-0.241)	(-0.230)	(-0.291)		(0.446)	(0.899)	(0.903)	(0.920)		(0.716)	(-0.571)	(-0.698)	(-0.692)		(1.655)	(1.046)	(1.059)	(1.123)
RMW_I		-0.109	-0.121	-0.007	-0.067		-0.078	-0.154	-0.083	-0.113		-0.226	-0.058	0.005	0.027		0.002	0.111	0.143	0.167
		(-0.290)	(-0.343)	(-0.018)	(-0.186)		(-0.192)	(-0.405)	(-0.221)	(-0.295)		(-0.494)	(-0.141)	(0.012)	(0.059)		(0.005)	(0.361)	(0.472)	(0.547)
CMA_I		0.270	0.379	0.605*	0.540		0.353	0.113	0.322	0.122		-0.472	0.176	0.303	0.444		-0.321	0.047	0.141	0.063
		(0.675)	(1.008)	(1.879)	(1.549)		(0.766)	(0.287)	(0.787)	(0.343)		(-1.190)	(0.539)	(0.673)	(1.116)		(-0.724)	(0.120)	(0.334)	(0.154)
MOM_I		0.248	0.244	0.211	0.168		-0.112	-0.076	-0.074	-0.041		0.168	0.147	0.031	0.009		0.686	0.638	0.631	0.681
		(0.717)	(0.658)	(0.584)	(0.457)		(-0.244)	(-0.167)	(-0.163)	(-0.092)		(0.365)	(0.343)	(0.066)	(0.019)		(1.406)	(1.326)	(1.300)	(1.375)
U			-0.441					-0.032					-0.738					-0.053		
			(-0.895)					(-0.082)					(-1.457)					(-0.182)		
SV				0.164					0.474					-0.334					0.180	
				(0.602)					(1.205)					(-0.621)					(0.728)	
RV					-0.318					0.287					-0.192					0.401
					(-0.777)					(0.909)					(-0.589)					(1.233)
$\bar{R}^2$	-1.519	-1.377	-0.415	-1.755	-1.069	-1.290	-1.642	-2.046	-0.421	-1.356	1.950	1.832	0.082	-2.616	-3.000	1.824	0.996	-0.311	-0.071	1.210
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 2.8
Cross-Section of Domestic ETP and Index Option Returns.

This table reports portfolio performance metrics for the cross-sections of ETP and index option returns domestically. The ETP (index) cross-section includes all ETP (index) option products displayed in Table 2.7.2 Panel (A) ((B)). The sample period is January 2006 to December 2015. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). Options are held to maturity. The volatility returns used for sorting are: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. The unconditional (U) portfolio return is the equally weighted average of all the ATM straddles available at the moment of portfolio formation. Option returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) option portfolios. Unconditional, high and low portfolio returns are presented as short positions. Panel (A) presents annualized average return (μ), its t-statistic (t-μ), annualized risk-adjusted return (α), its t-statistic (t-α) and annualized Sharpe ratios (SR). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), excess-kurtosis (Kur), maximum (Max) and minimum (Min) monthly returns in percentage and skewness (Skw). Panel (C) presents option portfolios market exposures: delta (Δ) and gamma (Γ) Greeks at the moment of portfolio formation, ex-post CAPM-β with respect to CRSP value weighted index (β), its t-statistic (t-β), and first order auto-correlation coefficient in percentage (ρ). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
Returns (A)	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
μ	8.07	11.29	5.25	5.59	10.05	6.58	3.29	2.79	3.68	1.65	0.92	5.20	0.82	3.42
t-μ	1.23	1.74	0.78	1.99	1.50	0.98	1.44	0.44	0.59	0.23	0.37	0.81	0.12	1.33
α	3.62	7.34	0.53	6.29	5.38	2.15	3.12	-0.85	0.84	-2.81	2.31	2.16	-3.63	4.62
t-α	0.55	1.09	0.08	2.32	0.81	0.31	1.37	-0.13	0.13	-0.40	0.94	0.32	-0.52	1.90
SR	0.37	0.52	0.24	0.60	0.45	0.30	0.43	0.13	0.17	0.07	0.09	0.24	0.03	0.37
Risk (B)														
Std	21.55	21.59	21.85	9.39	22.09	21.61	7.59	21.57	21.24	24.49	9.69	21.36	24.07	9.26
Kur	13.45	13.32	14.13	5.28	14.04	14.06	1.26	10.62	7.57	11.78	1.12	9.22	12.51	1.64
Max	6.61	6.60	6.78	6.47	6.58	6.78	5.51	6.22	7.00	6.99	8.47	7.00	6.99	9.53
Min	-31.30	-28.56	-32.45	-12.69	-31.43	-32.39	-7.71	-29.68	-26.70	-34.39	-8.63	-26.69	-34.54	-7.65
Skw	-3.19	-3.25	-3.18	-1.11	-3.32	-3.10	-0.61	-2.78	-2.30	-2.91	-0.19	-2.57	-2.96	0.36
Exposure (C)														
Δ	0.42	0.41	0.42	-0.01	0.40	0.43	-0.03	0.45	0.45	0.45	0.00	0.45	0.45	0.00
Γ	0.15	0.15	0.16	-0.01	0.18	0.13	0.05	0.03	0.03	0.03	0.00	0.04	0.02	0.01
β	0.66	0.63	0.69	-0.05	0.73	0.62	0.11	0.61	0.53	0.71	-0.14	0.55	0.69	-0.11
t-β	3.10	3.06	3.15	-0.58	3.55	2.74	2.72	2.99	2.74	2.97	-2.48	2.82	2.88	-1.84
ρ	-5.36	-4.51	-5.47	-8.62	-6.55	-3.30	-0.11	-6.12	-6.63	-9.42	-4.64	-6.04	-7.17	2.30

Table 2.9

Alpha and Factor Exposures of Cross-Sectional Long-Short Domestic ETP and Index Portfolios.

This table reports time series regressions for ETP and index cross-sectional long-short option strategies domestically. The dependent variable is an ETP or index long-short option portfolio sorted either by IV returns or VSR returns. The long-short option returns correspond to those in in Table 2.8 for the period 2006-2015. The independent variables span over the following factors models. Domestic (D) and international (I) equity factors models comprised of Fama and French (2015) five factors model in addition to Carhart (1997) momentum factor. These factors comprise market (MKT), size (SMB), value (HML), profitability (RMW), investment (CMA) and momentum (MOM). Both domestic and international equity factors models are from Kenneth French's website. Additional models comprise the following volatility factors. The corresponding unconditional (U) option portfolio return of the dependent variable. A hedge fund short volatility (SV) index comprised of 16 hedge funds which take net short positions in volatility related products. A hedge fund relative volatility value (RV) index comprised of 40 hedge funds which take long-short positions in volatility related products. Both of the volatility factors are from Bloomberg. While running regressions with volatility factors, domestic or international equity exposures are controlled, besides the market factor due to collinearity with the volatility factor. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the option portfolio return by β percentage points monthly. Alphas are expressed in percentage terms and annualized. Newey and West (1987) t-statistics computed with three lags are used to account for heteroskedasticity and autocorrelation. Adjusted R^2 is in percentage terms. N is the number of observations. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										Index									
	IV^r_{H-L}					VSR^r_{H-L}					IV^r_{H-L}					VSR^r_{H-L}				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
α	6.290**	5.449*	5.826**	6.927**	6.444	3.117	3.249	3.721	3.923*	0.345	2.310	2.118	1.618	4.346**	5.419	4.615*	3.978*	3.824	6.932***	6.075*
	(2.323)	(1.735)	(2.030)	(2.340)	(1.254)	(1.374)	(1.566)	(1.625)	(1.688)	(0.122)	(0.935)	(0.925)	(0.635)	(2.068)	(1.558)	(1.904)	(1.750)	(1.490)	(3.196)	(1.714)
MKT_D	-0.342					0.398*					-0.771**					-0.838***				
	(-0.828)					(1.784)					(-2.573)					(-2.669)				
SMB_D	0.138		0.041	0.102	0.047	0.150		0.272	0.279	0.227	-0.418		-0.533	-0.466	-0.593*	0.185		0.049	0.139	-0.027
	(0.547)		(0.166)	(0.448)	(0.206)	(0.584)		(1.000)	(1.048)	(0.883)	(-1.236)		(-1.644)	(-1.435)	(-1.730)	(0.564)		(0.161)	(0.451)	(-0.080)
HML_D	0.999**		0.979**	0.857*	0.961**	0.262		0.282	0.256	0.384	0.199		0.133	-0.187	0.031	0.263		0.193	-0.169	0.137
	(2.392)		(2.270)	(1.860)	(2.106)	(0.958)		(1.011)	(0.889)	(1.440)	(0.515)		(0.297)	(-0.557)	(0.067)	(0.793)		(0.537)	(-0.464)	(0.356)
RMW_D	0.305		0.404	0.347	0.400	0.021		-0.098	-0.108	-0.074	-0.503		-0.343	-0.439	-0.304	-0.337		-0.156	-0.272	-0.108
	(1.222)		(1.407)	(1.237)	(1.338)	(0.076)		(-0.354)	(-0.394)	(-0.289)	(-1.580)		(-1.088)	(-1.520)	(-0.943)	(-1.390)		(-0.596)	(-1.317)	(-0.397)
CMA_D	-0.087		-0.085	-0.101	-0.077	-0.133		-0.136	-0.138	-0.176	0.091		0.062	0.050	0.147	0.184		0.155	0.137	0.220
	(-0.315)		(-0.300)	(-0.378)	(-0.293)	(-0.569)		(-0.571)	(-0.589)	(-0.792)	(0.369)		(0.251)	(0.202)	(0.588)	(0.817)		(0.672)	(0.629)	(0.957)
MOM_D	0.422		0.454	0.390	0.432	0.135		0.098	0.083	0.211	0.056		0.152	-0.051	-0.015	0.046		0.147	-0.076	0.034
	(1.274)		(1.508)	(1.160)	(1.144)	(0.627)		(0.415)	(0.349)	(0.947)	(0.195)		(0.501)	(-0.174)	(-0.048)	(0.160)		(0.568)	(-0.269)	(0.112)
MKT_I		-0.526					0.485*					-0.998***					-0.661*			
		(-1.141)					(1.684)					(-2.784)					(-1.739)			
SMB_I		0.209					0.417**					0.032					0.249			
		(1.273)					(2.464)					(0.171)					(1.495)			
HML_I		1.545***					0.430					0.545					0.337			
		(3.880)					(1.449)					(1.422)					(0.875)			
RMW_I		0.348					-0.003					-0.149					-0.166			
		(1.127)					(-0.012)					(-0.543)					(-0.611)			
CMA_I		-0.561					-0.056					-0.321					0.218			
		(-1.369)					(-0.149)					(-1.038)					(0.704)			
MOM_I		0.520*					0.162					0.151					0.004			
		(1.787)					(0.633)					(0.535)					(0.017)			
U			-0.006					-0.038					-0.629***					-0.619*		
			(-0.013)					(-0.151)					(-2.830)					(-1.884)		
SV				-0.372					-0.085					-1.042***					-1.167***	
				(-1.094)					(-0.468)					(-5.151)					(-4.654)	
RV					-0.077					0.410**					-0.516*					-0.323
					(-0.186)					(2.564)					(-1.826)					(-1.161)
$\bar{R}^2$	3.350	12.249	2.234	3.993	2.314	1.823	9.404	-0.466	-0.354	2.966	4.451	3.523	4.143	12.046	2.474	2.928	4.564	1.358	13.783	-2.521
N	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119

Table 2.10

Fama-MacBeth Regressions: Cross-Section of International and Domestic Option Returns.

This table reports Fama and MacBeth (1973) regressions on international and domestic option returns cross-sections. International products are reported in Table 2.7.1, while domestic products are reported in Table 2.7.2. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{2.7}$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility Return$_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year market index daily returns and squared returns, respectively. The market index is either MSCI or CRSP index depending if the option underlying is an international or domestic security. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										Domestic									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.765***	0.804***	0.759***	0.864***	0.666***	0.780***	0.772***	0.766***	0.824***	0.655***	0.388***	0.477***	0.406***	0.368***	0.288***	0.232***	0.294***	0.283***	0.274***	0.077
	(6.697)	(6.999)	(6.675)	(8.229)	(5.136)	(8.005)	(7.483)	(6.831)	(8.897)	(4.866)	(3.977)	(4.246)	(4.041)	(3.283)	(3.020)	(3.053)	(3.742)	(3.142)	(3.462)	(0.934)
Skw		0.044					0.037					0.111					0.126			
		(0.433)					(0.378)					(0.892)					(1.054)			
Kur		0.191*					0.139					0.023					-0.005			
		(1.662)					(1.291)					(0.215)					(-0.047)			
Delta			-0.434***					-0.308**					-0.146					-0.119		
			(-3.840)					(-2.346)					(-1.464)					(-1.144)		
Beta			0.376***					0.310***					0.109					0.142		
			(3.331)					(2.932)					(0.946)					(1.218)		
CoSkw				-0.133					-0.101					0.186					0.188	
				(-0.959)					(-0.721)					(1.507)					(1.564)	
MOM				-0.045					-0.016					-0.003					-0.033	
				(-0.363)					(-0.137)					(-0.031)					(-0.301)	
Dollar Volume					-0.172					-0.063					-0.092					0.018
					(-1.593)					(-0.554)					(-0.507)					(0.092)
Dollar OI					-0.022					-0.049					0.067					-0.041
					(-0.226)					(-0.517)					(0.351)					(-0.194)
BAS					0.457***					0.410***					0.197**					0.314***
					(4.461)					(3.808)					(2.258)					(3.150)
$\bar{R}^2$	6.033	8.446	13.286	11.035	11.138	6.733	9.016	13.038	11.879	10.658	7.933	18.765	18.639	20.379	7.640	5.285	15.108	15.660	17.933	5.717
N	4301	4301	4301	4301	4301	4301	4301	4301	4301	4301	5099	5099	5099	5099	5099	5099	5099	5099	5099	5099

Table 2.11
Fama-MacBeth Regressions: Dispersion Trading of International and Domestic Option Returns.

This table reports Fama and MacBeth (1973) regressions on international and domestic dispersion trading option returns. Dispersion pairs are reported in Table 2.7.3. Each month cross-sectional regressions of monthly dispersion trading option returns on portfolio construction dispersion trading volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Dispersion,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t}^{\text{Dispersion}} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau}$$

where $r_{i,t+\tau}^{\text{Dispersion,USD}}$ is the dispersion trading option returns on the i ETP product minus the corresponding index option return at expiration day $t+\tau$. Volatility Return$_{i,t}^{\text{Dispersion}}$ is the dispersion trading volatility return at portfolio formation which can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. All the control variables are the difference between ETP and index variable values. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year market index daily returns and squared returns, respectively. The market index is either MSCI or CRSP index depending if the option underlying is an international or domestic security. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	International										Domestic									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	1.361***	1.342***	1.432***	1.345***	1.277***	1.062***	1.030***	1.136***	1.011***	0.835***	0.143	0.172	0.136	-0.041	0.197	0.144	0.090	0.089	0.068	0.148
	(7.372)	(6.915)	(7.280)	(5.235)	(4.863)	(5.836)	(4.855)	(3.991)	(5.090)	(3.046)	(1.017)	(1.061)	(0.942)	(-0.314)	(1.296)	(1.051)	(0.623)	(0.564)	(0.449)	(0.887)
Skw		0.110					0.072					0.177					0.161			
		(0.327)					(0.223)					(1.078)					(0.984)			
Kur		-0.172					-0.287					0.121					-0.079			
		(-0.503)					(-0.829)					(0.882)					(-0.590)			
Delta			-0.407*					-0.246					-0.089					-0.151		
			(-1.804)					(-0.984)					(-0.659)					(-1.155)		
Beta			0.411**					0.324					-0.047					-0.108		
			(2.036)					(1.442)					(-0.235)					(-0.562)		
CoSkw				-0.469**					-0.223					0.242					0.196	
				(-2.025)					(-1.051)					(1.454)					(1.082)	
MOM				-0.204					-0.124					0.104					-0.004	
				(-0.940)					(-0.594)					(0.712)					(-0.026)	
Dollar Volume					-0.153					-0.006					0.055					0.048
					(-0.451)					(-0.015)					(0.067)					(0.070)
Dollar OI					-0.176					-0.486					-0.198					-0.262
					(-0.511)					(-1.302)					(-0.232)					(-0.377)
BAS					0.420					0.721***					0.110					0.090
					(1.508)					(2.881)					(0.868)					(0.664)
$\bar{R}^2$	14.810	21.907	24.929	20.415	21.266	13.610	21.596	24.475	18.442	21.051	12.964	23.530	26.665	25.577	10.762	11.427	21.360	24.168	25.958	9.499
N	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1871	1871	1871	1871	1871	1871	1871	1871	1871	1871

Table 2.12
Fama-MacBeth Regressions: Cross-Section of International ETP and Index Option Returns.

This table reports Fama and MacBeth (1973) regressions on international ETP and index option returns cross-sections. International ETP and index products are reported in Table 2.7.1. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r^{\text{Short,USD}}_{i,t+\tau} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{2.8}$$

where $r^{\text{Short,USD}}_{i,t+\tau}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility $\text{Return}_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year MSCI market index daily returns and squared returns, respectively. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										Index									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.973***	0.960***	1.027***	1.090***	0.863***	0.851***	0.816***	0.940***	0.938***	0.686***	0.340***	0.572***	0.206	0.363***	0.421***	0.366***	0.401**	0.142	0.364**	0.477***
	(6.692)	(6.527)	(6.177)	(7.302)	(4.389)	(6.300)	(5.941)	(5.471)	(6.469)	(3.699)	(2.683)	(3.810)	(1.261)	(2.748)	(3.074)	(2.695)	(2.543)	(0.870)	(2.393)	(2.640)
Skw		-0.010					0.033					0.026					-0.205			
		(-0.068)					(0.223)					(0.110)					(-0.723)			
Kur		0.384***					0.319**					0.022					-0.206			
		(2.880)					(2.237)					(0.078)					(-0.664)			
Delta			-0.271*					-0.177					0.185					0.252*		
			(-1.834)					(-1.075)					(1.109)					(1.758)		
Beta			0.205					0.197					0.134					0.095		
			(1.220)					(1.204)					(0.838)					(0.582)		
CoSkw				-0.106					-0.080					-0.063					-0.185	
				(-0.679)					(-0.491)					(-0.416)					(-1.153)	
MOM				-0.094					-0.079					-0.098					0.040	
				(-0.574)					(-0.504)					(-0.807)					(0.352)	
Dollar Volume					-0.421					-2.239					-0.258					-0.002
					(-0.243)					(-0.979)					(-1.559)					(-0.013)
Dollar OI					0.441					2.242					0.127					0.026
					(0.250)					(0.960)					(0.791)					(0.173)
BAS					0.408**					0.492***					0.085					0.171
					(2.274)					(3.147)					(0.667)					(1.290)
$\bar{R}^2$	9.388	12.451	16.272	14.057	7.230	10.110	12.610	15.684	14.236	6.786	10.551	13.867	18.240	16.529	18.567	9.832	13.801	16.260	17.183	19.017
N	2448	2448	2448	2448	2448	2448	2448	2448	2448	2448	1845	1845	1845	1845	1845	1845	1845	1845	1845	1845

Table 2.13
Fama-MacBeth Regressions: Cross-Section of Domestic ETP and Index Option Returns.

This table reports Fama and MacBeth (1973) regressions on domestic ETP and index option returns cross-sections. Domestic ETP and index products are reported in Table 2.7.2. Each month cross-sectional regressions of monthly option returns on portfolio construction volatility returns plus a set of control variables are estimated.

$$r_{i,t+\tau}^{\text{Short,USD}} = \lambda_{1,t} \cdot \text{Volatility Return}_{i,t} + \Lambda_t' \mathbf{Z}_{i,t} + \varepsilon_{i,t+\tau} \tag{2.9}$$

where $r_{i,t+\tau}^{\text{Short,USD}}$ is the option straddle return on the product i at expiration day $t+\tau$. Volatility Return$_{i,t}$ is the product i ex-ante volatility return at portfolio construction. The volatility returns can be either model dependent (IV) or model-free (VSR) return. $\lambda_{1,t}$ is the volatility return coefficient. $\mathbf{Z}_{i,t}$ is a vector of control characteristics for product i at time t. The controls considered are the following. Underlying asset's skewness (Skw) and kurtosis (Kur) estimated from previous year daily data. Underlying asset's momentum (MOM) estimated as the cumulative return over the last twelve months by skipping the most recent month. Market beta (Beta) and coskewness beta (CoSkw) which are estimated by an univariate regression of the underlying returns on previous year CRSP market index daily returns and squared returns, respectively. Additional control variables include: absolute delta (Delta), dollar volume (Dollar Volume), dollar open interest (Dollar OI) and bid-ask spread (BAS) average between call and put options used to construct the straddle. Λ_t is a column vector of control coefficients. Monthly cross-sectional regressions have both the dependent and independent variables demeaned. The independent variables are also standardized to unit variance. The factor exposure means that a one-standard-deviation increase in the regressor implies a change in the next month option returns by β percentage points. The time-series average of the estimated coefficients are reported in percentage. Newey and West (1987) t-statistics with three lags are reported in brackets. Adjusted R^2 is in percentage terms and it is the average over time of the adjusted R^2 in each cross-sectional regression. ***, **, * represent statistical significance at 1%, 5% and 10% level, respectively.

	ETP										Index									
	IV^r					VSR^r					IV^r					VSR^r				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Volatility Return	0.422***	0.534***	0.427***	0.369***	0.347***	0.243***	0.289***	0.306***	0.276***	0.075	0.145	0.078	0.242*	0.305**	0.052	0.110	0.200**	0.321**	0.116	0.107
	(3.666)	(3.922)	(3.608)	(2.955)	(3.067)	(2.598)	(2.884)	(2.633)	(2.711)	(0.722)	(1.433)	(0.550)	(1.766)	(2.086)	(0.397)	(1.182)	(2.250)	(2.337)	(1.132)	(0.751)
Skw		0.159					0.186					-0.114					-0.125			
		(1.121)					(1.361)					(-0.653)					(-0.557)			
Kur		0.016					-0.009					-0.112					0.001			
		(0.145)					(-0.090)					(-0.555)					(0.006)			
Delta			-0.077					-0.024					-0.171*					-0.219**		
			(-0.708)					(-0.209)					(-1.903)					(-2.060)		
Beta			0.059					0.095					0.097					0.192		
			(0.461)					(0.706)					(0.565)					(1.351)		
CoSkw				0.201					0.238*					0.170					0.158	
				(1.559)					(1.797)					(1.218)					(1.346)	
MOM				0.014					-0.054					-0.414**					-0.178	
				(0.122)					(-0.454)					(-2.562)					(-1.120)	
Dollar Volume					-0.033					0.044					3.407					1.952
					(-0.064)					(0.086)					(1.052)					(0.775)
Dollar OI					0.014					-0.045					-3.419					-2.009
					(0.027)					(-0.089)					(-1.055)					(-0.796)
BAS					0.099					0.240*					0.081					-0.044
					(0.935)					(1.912)					(0.761)					(-0.282)
$\bar{R}^2$	8.796	19.537	18.875	20.280	9.285	6.165	15.986	15.530	18.312	7.902	21.649	46.037	39.466	50.034	30.081	15.770	38.910	33.534	44.273	25.474
N	3819	3819	3819	3819	3819	3819	3819	3819	3819	3819	1280	1280	1280	1280	1280	1280	1280	1280	1280	1280

Table 2.14

Ex-Ante and Ex-Post Volatility Returns of International and Domestic Portfolios.

This table reports ex-ante and ex-post volatility returns for international and domestic option portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Volatility returns can be either implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). The sample period is January 2006 to December 2015. Panel (A) reports volatility returns for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table 2.7.1 (2.7.2). Each fourth Friday of the month, volatility returns are sorted in descending order by previous day ex-ante volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio is the equally weighted average of all the volatility returns available at the moment of portfolio formation. Panel (B) reports dispersion trading volatility returns for international and domestic dispersion trading portfolios. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table 2.7.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day ex-ante volatility returns difference, equation (2.2). Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP volatility returns are sold and the corresponding index volatility returns are bought. The high (low) dispersion trading portfolio is the tercile among the ETP and index pairs with the largest (smallest) ex-ante volatility return dispersion. The long-short dispersion trading portfolio is the difference between 50% of the high and 50% of the low dispersion tercile. The unconditional (U) dispersion trading portfolio is the equally weighted average of ETP minus index volatility returns pairs. The table includes unconditional (U), high (H), low (L) and high minus low (H-L) portfolios. Both of the Panels report the following measures. Ex-ante implied volatility or volatility swap rate level at the moment of portfolio construction (ex-ante Vol). Ex-ante underlying assets' realized volatility over the previous 12 months at the moment of portfolio construction (ex-ante Std). Ex-ante volatility return (ex-ante Vol. Ret.) and its t-statistic. Ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. The unconditional basket is always expressed in implied volatility terms.

	International							Domestic						
		IV^r			VSR^r				IV^r			VSR^r		
	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
Cross-Section (A)														
ex-ante Vol	24.91	28.85	22.87	5.97	38.86	22.94	15.92	20.13	21.96	18.97	3.00	24.36	19.14	5.22
ex-ante Std	24.43	22.43	27.18	-4.75	22.72	27.00	-4.28	20.13	19.70	20.88	-1.18	18.92	21.41	-2.49
ex-ante Vol. Ret.	-3.93	11.58	-18.80	29.74	25.07	-17.43	41.70	-4.27	4.25	-12.23	16.19	15.10	-12.33	26.94
t-statistic	-1.08	3.88	-4.35	21.09	7.63	-4.18	17.00	-1.00	1.11	-2.58	15.02	4.71	-2.63	16.84
ex-post Vol. Ret.	3.88	12.11	-2.48	14.39	26.22	-3.14	29.11	2.94	6.95	-0.38	7.25	17.64	-1.90	19.33
t-statistic	1.63	5.74	-0.91	13.88	8.64	-1.09	13.84	1.02	2.58	-0.12	9.37	6.18	-0.56	19.08
Dispersion Trading (B)														
ex-ante Vol	7.11	14.74	3.04	5.85	28.93	3.85	12.54	1.24	1.96	1.21	0.37	4.21	1.07	1.57
ex-ante Std	5.24	3.13	7.63	-2.25	3.10	6.98	-1.94	1.23	0.00	3.34	-1.67	-0.45	3.63	-2.04
ex-ante Vol. Ret.	2.74	22.89	-14.05	18.38	40.70	-8.50	24.66	0.38	8.25	-8.01	8.10	15.70	-10.60	13.11
t-statistic	1.99	12.93	-6.90	16.44	16.33	-3.44	17.64	0.87	9.34	-13.23	14.34	9.56	-12.12	15.02
ex-post Vol. Ret.	1.82	16.55	-10.70	13.53	34.70	-8.50	21.55	0.13	2.96	-2.64	2.79	10.98	-6.57	8.76
t-statistic	1.21	8.03	-4.78	10.80	13.26	-2.94	14.61	0.27	3.32	-3.66	5.30	10.59	-12.27	16.52

Table 2.15

Ex-Ante and Ex-Post Volatility Returns of ETP and Index Portfolios.

This table reports ex-ante and ex-post volatility returns for ETP and Index portfolios. Ex-ante (ex-post) volatility returns are constructed as one minus the ratio of previous year (ex-post) realized volatility to time t implied volatility. The underlying ex-post realized volatility is calculated from time t to the option expiration day $t+\tau$. Volatility returns can be either implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). The sample period is January 2006 to December 2015. Each fourth Friday of the month, volatility returns are sorted in descending order by previous day ex-ante volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The unconditional (U) portfolio is the equally weighted average of all the volatility returns available at the moment of portfolio formation. Panel (A) reports volatility returns for the cross-sections of ETP and index option returns internationally. The ETP (index) cross-section includes all ETP (index) option products displayed in Table 2.7.1 Panel (A) ((B)). In this table, Panel (B) reports volatility returns for the cross-sections of ETP and index option returns domestically. The ETP (index) cross-section includes all ETP (index) option products displayed in Table 2.7.2 Panel (A) ((B)). This table includes unconditional (U), high (H), low (L) and high minus low (H-L) portfolios. Both of the Panels report the following measures. Ex-ante implied volatility or volatility swap rate level at the moment of portfolio construction (ex-ante Vol). Ex-ante underlying assets' realized volatility over the previous 12 months at the moment of portfolio construction (ex-ante Std). Ex-ante volatility return (ex-ante Vol. Ret.) and its t-statistic. Ex-post volatility return (ex-post Vol. Ret.) and its t-statistic. Both of the volatility returns are annualized averages in percentage terms. Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. The unconditional basket is always expressed in implied volatility terms.

	ETP							**Index**						
		IV^r			VSR^r				IV^r			VSR^r		
	U	H	L	H-L	H	L	H-L	U	H	L	H-L	H	L	H-L
International (A)														
ex-ante Vol	28.68	34.41	25.59	8.82	48.20	26.61	21.59	20.21	22.15	18.67	3.48	21.71	18.75	2.95
ex-ante Std	27.72	24.94	30.66	-5.71	24.23	30.91	-6.68	20.39	19.46	21.46	-2.01	18.69	21.99	-3.29
ex-ante Vol. Ret.	-3.30	15.07	-19.27	33.65	32.82	-15.55	47.56	-5.20	6.59	-17.35	23.41	8.77	-18.37	26.57
t-statistic	-0.83	4.28	-4.38	22.93	9.04	-3.51	18.78	-1.54	2.39	-4.20	13.93	3.21	-4.67	17.03
ex-post Vol. Ret.	4.76	16.53	-3.79	19.98	35.14	-2.69	37.42	2.29	5.41	-0.52	5.85	8.34	-2.87	11.11
t-statistic	1.81	7.29	-1.15	12.07	10.75	-0.77	16.22	0.98	2.18	-0.22	5.50	3.36	-1.17	9.29
Domestic (B)														
ex-ante Vol	20.43	22.49	19.11	3.38	24.94	19.21	5.74	19.24	20.43	18.68	1.75	23.37	19.47	3.90
ex-ante Std	20.29	19.64	21.22	-1.58	18.84	21.68	-2.83	19.65	19.87	20.02	-0.14	18.90	20.89	-1.99
ex-ante Vol. Ret.	-3.87	5.66	-12.77	18.09	16.81	-13.07	29.32	-5.40	-0.04	-10.58	10.37	10.84	-9.49	20.07
t-statistic	-0.91	1.50	-2.68	14.33	5.65	-2.77	15.67	-1.22	-0.01	-2.28	14.94	2.49	-2.07	12.08
ex-post Vol. Ret.	3.38	8.18	-0.66	8.75	18.90	-2.03	20.71	1.52	2.83	0.52	2.26	15.03	-0.58	15.49
t-statistic	1.20	3.07	-0.22	10.35	6.72	-0.59	18.91	0.50	0.96	0.17	2.53	4.18	-0.17	9.44

Table 2.16

International and Domestic Option Strategies: Returns Computed at 25% of Effective to Quoted Spread.

This table reports portfolio performance metrics for international and domestic option strategies. The sample period is January 2006 to December 2015. The table presents two types of option schemes, cross-sectional and dispersion trading strategies, and a set of benchmark indexes. Option returns are computed by executing trades at 25% of the effective to quoted bid-ask spread. Returns are denominated in US dollars, expressed in excess of US risk-free rate and options are held to maturity. In addition, trades are executed on options with either positive volume or positive previous day open interest. The cross-sectional option schemes show portfolio performance metrics for the cross-sections of international and domestic option returns. The international (domestic) cross-section includes all ETP and index option products displayed in Table 2.7.1 (2.7.2). Ex-ante volatility returns are the sorting variable. There are two types of sorts: implied volatility returns (IV^r) or volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Each fourth Friday of the month, ATM straddles are sorted in descending order by previous day volatility returns and assigned to one of three equally weighted tercile portfolios. The long-short portfolio sells the expensive tercile (high) and buys the cheap tercile (low). The table includes high minus low (H-L) option portfolios. The dispersion trading option schemes show portfolio performance metrics for international and domestic dispersion trading option strategies. The international (domestic) dispersion trading pairs include ETP and index options displayed in Table 2.7.3 Panel (A) ((B)). Each fourth Friday of the month, ETP and index dispersion pairs are ranked in descending order by previous day volatility returns difference. Then, they are assigned to one of three equally weighted tercile portfolios. Successively, ETP ATM straddles are sold and the corresponding index ATM straddles are bought. The high dispersion trading portfolio is the tercile among the ETP and index pairs with the largest ex-ante volatility return dispersion. The table includes high (H) dispersion trading portfolios. Panel (A) presents annualized average return (μ), annualized Sharpe ratio (SR). annualized risk-adjusted return (α) and its t-statistic (t-α). Returns and risk-adjusted returns are in percentage. Risk-adjusted returns are with respect to an equity six factors model comprised of Fama and French (2015) five factors model plus Carhart (1997) momentum factor. Panel (B) shows risk measures: annualized standard deviations in percentage (Std), skewness (Skw), CAPM-β with respect to CRSP value weighted index (β) and its t-statistic (t-β). Newey and West (1987) inference with three lags is used to account for heteroskedasticity and autocorrelation. Lastly, the benchmark indexes include: CRSP value weighted index, MSCI world index, a hedge fund short volatility (SV) index and a hedge fund relative volatility value (RV) index.

	Cross-Section				**Dispersion Trading**				**Benchmarks**			
	International		**Domestic**		**International**		**Domestic**					
Returns (A)	IV^r_{H-L}	VSR^r_{H-L}	IV^r_{H-L}	VSR^r_{H-L}	IV^r_H	VSR^r_H	IV^r_H	VSR^r_H	CRSP	MSCI	SV	RV
μ	7.11	9.46	-0.27	-2.12	11.64	12.78	-1.90	-2.98	5.83	3.93	7.79	9.04
SR	0.81	1.16	-0.04	-0.25	0.95	1.11	-0.18	-0.26	0.37	0.24	0.86	2.41
α	8.71	11.20	-0.12	-2.07	13.11	13.34	-2.37	-3.76	0.00	-2.07	5.46	8.47
t-α	3.17	4.25	-0.06	-0.77	3.51	4.01	-0.71	-0.97	0.76	-1.60	1.97	5.36
Risk (B)												
Std	8.75	8.17	7.26	8.37	12.32	11.51	10.64	11.59	15.69	16.70	9.07	3.76
Skw	0.62	0.69	-0.33	0.55	-0.17	-0.38	-0.99	-0.88	-0.89	-1.00	-3.04	0.06
β	-0.19	-0.14	0.01	0.06	-0.13	-0.10	-0.06	0.10	1.00	1.03	0.31	0.05
t-β	-3.51	-2.88	0.16	0.60	-1.94	-1.11	-1.18	1.53		44.48	3.37	1.71

2.7 Appendix

2.7.1 Further Data Information and Procedures

- *Option data variables.* I obtain option pricing data containing: the date of the option price record, strike price, call-put flag, closing bid and ask option prices, the closing trade price or the settlement price published by the exchange of the option (if available), volume, open interest, implied volatility, option sensitivities (Greeks) and adjustment factor for splits.

- *Cross-sectional option portfolios, variables aggregation.* For each type of basket-portfolio unconditional, high tercile and low tercile, I compute the equally weighted cross-sectional average of the following variables: option straddle returns, ex-ante volatility returns, ex-post volatility returns, implied volatility level, volatility swap rate level, ex-ante realized volatility level, call and put average absolute delta and gamma. The long-short portfolio is the high tericle portfolio minus the low tercile portfolio variable value.

- *Dispersion trading option portfolios, variables aggregation.* For each of the following variables I take the difference between the ETP and index option variable value: option straddle returns, ex-ante volatility returns, ex-post volatility returns, implied volatility level, volatility swap rate level, ex-ante realized volatility level, call and put average absolute delta and gamma. Then, I compute the equally weighted average across ETP-index pairs for each basket portfolio and for each variable. I do this procedure for the following baskets: unconditional, high tercile and low tercile. The long-short dispersion portfolio is 50% of the high minus 50% of the low tercile portfolio variable value.

- *Cash flows synchronization.* I synchronize cash flows as follows, if the expected entry day is before the fourth Friday of the month Taiwan and Australia index options are not included in the portfolio formation. This ensures full cash flows availability for next month portfolio construction independently from the first calendar day of the month. While if the expected entry day is before the end of the month Hong Kong index options are not included in the portfolio formation.

- *Taiwan index options.* I find inconsistency in monthly expiration dates among Taiwanese index options. Taiwanese index options are supposed to expire on the third Wednesday of the month.[23] Nonetheless, recording errors in the option data have swapped them with third Fridays expiration, which is an expiration cycle that does not exist in monthly Taiwanese options. This issue is confirmed by the data provider and the exchange as of 2017-08-31. I created an algorithm that identifies monthly Wednesday expiring options, with 100% precision for the period 2006-2015. In addition, this data has an institutional recording error in exercise option style. Taiwan index options are European, while the data swaps between European and American style flags.

- *Merging options by ID and strike price.* I identify option securities by their unique option ID. In case there is a disappearance of options IDs from one day to another for no institutional reason, I identify options from day $t-1$ to t by strike price for each term-structure point and for each call / put option type. I cross check the merge by no violation of arbitrage across-strikes and check

[23] http://www.taifex.com.tw/eng/eng2/TXO.asp

the evolution of securities from time $t-1$ to t. This issue can occur sporadically for Taiwan index options. Exclusion of these few IDs exceptions does not effect the result of this paper.

- *Missing option prices for international index options.* in case an international index option product has a missing price for a specific strike price, -99.99, I exclude that strike from the computations. Depending on when this issue occur, I exclude that strike either at the moment of portfolio formation or at the moment of trade execution (moving to its closest OTM strike available).

- *Software unit tests:* I reproduce Israelov et al. (2017) empirical study and obtain similar results under their research design. Furthermore, I use as inputs module one of the following return values: (i) zero returns for all assets, (ii) a constant, (iii) S&P 500 cash (or general) index returns and (iv) the negative of S&P 500 cash (or general) index returns. I obtain the following outputs module for unconditional, high, low and long-short portfolios: (i) zero everywhere, (ii) a constant for unconditional, high and low baskets and zero for long-short, (iii) S&P 500 cash (or general) index returns for unconditional, high and low baskets returns and zero returns for long-short baskets, (iv) as in case (iii) but reversed. Regarding dispersion trading portfolios, I obtain zero returns everywhere. Lastly, to grantee a correct merging of option contracts and specifications, I tested odd and even contract months by assigning to the latter a value of -1000. The output results in a -1000 value for even months and the option returns value for odd months.

2.7.2 Contractual Information

Websites, as of 2017-08-31:[24]

- **Australia:** (S&P/ASX 200) http://www.asx.com.au/products/equity-options/options-contract-speci htm

- **Belgium:** (BEL-20) https://derivatives.euronext.com/en/products/index-options/BEL-DBRU/contract-specification

- **Canada:** (S&P/TSX 60) https://www.m-x.ca/produits_indices_sxo_en.php

- **Finland:** (OMXH25) http://www.eurexchange.com/exchange-en/products/idx/hex/OMXH25-Options/17082

- **France:** (CAC 40) https://derivatives.euronext.com/en/products/stock-options/PXA-DPAR/contract-specification

- **Germany:** (DAX) http://www.eurexchange.com/exchange-en/products/idx/dax/DAX--Options/17252

- **Hong Kong:** (Hang Seng) https://www.hkex.com.hk/eng/prod/drprod/hkifo/options.htm

- **Italy:** (FTSE MIB) http://www.borsaitaliana.it/derivati/specifichecontrattuali/ftsemiboptions.en.htm

[24]Further institutional data sources are option clearing corporation and options industry council: https://www.theocc.com/ and https://www.optionseducation.org/about_oic.html, respectively

- **Japan:** (Nikkei 225) http://www.jpx.co.jp/english/derivatives/products/domestic/225options/01.html
- **Korea:** (KOSPI 200) http://global.krx.co.kr/contents/GLB/02/0201/0201040202/GLB0201040202.jsp
- **The Netherlands:** (Aex-Index) https://derivatives.euronext.com/en/products/index-options/AEX-DAMS/contract-specification
- **Spain:** (IBEX 35) http://www.meff.com/ing/Financial-Derivatives/Options-on-IBEX-35
- **Sweden:** (OMXS 30) http://www.nasdaqomx.com/transactions/markets/optionsfutures/europe/product-information/index-options
- **Switzerland:** (SMI) http://www.eurexchange.com/exchange-en/products/idx/smi/SMI--Options/19508
- **Taiwan:** (TXO) http://www.taifex.com.tw/eng/eng2/TXO.asp
- **UK:** (FTSE-100) https://www.theice.com/products/38716770/FTSE-100-Index-Option
- **USA:** (SPX) http://www.cboe.com/products/stock-index-options-spx-rut-msci-ftse/s-p-500-index
- **ETP options and domestic index options:** http://www.cboe.com/

2.7.3 International Index Option Data Before January 2006

I choose to study option returns from January 2006 onward for the following reasons: (i) availability of international ETP option data from January 2006 and (ii) international index option higher pricing and contractual data quality since January 2006. In this Appendix, I outline the main data concerns regarding international index options for the period between 2002-01-01 and 2005-12-31. The OptionMetrics IvyDB-Global Indexes database is received as of 2017-June-30.

- *Australia:* I could not collect exercise settlement values and contractual data before 2006. In addition, I find that Australian index options have missing pricing data for the period between 2005-01-01 and 2005-12-31. This issue is confirmed by the data provider as of 2017-08-31.
- *Belgium:* the Belgium index options have several expiration months missing in 2003, this is also confirmed by the data provider as of 2017-08-31.
- *France:* the France index options have missing expiration months between 2005-09-16 and 2005-12-16. The data provider confirmed this hole in the database and the exchange doesn't have the data itself as of 2017-08-31.
- *Japan:* the Japanese index options have several missing expiration months during 2004. The data provider confirms this issue as of 2017-08-31.
- *Netherlands:* The Dutch index options have missing contractual information over the sample period. The Dutch index options have missing expiration contracts in mid 2002 and between 2004-12-17 and 2005-06-17. The data provider confirms this data problem as of 2017-08-31. The Netherlands index options have missing contractual information over the sample period.

- *Taiwan:* I find inconsistency in monthly expiration dates among Taiwanese index options. Taiwanese index options are supposed to expire on the third Wednesday of the month.[25] Nonetheless, recording errors in the option data have swapped them with third Fridays expiration, which is an expiration cycle that does not exist in monthly Taiwanese options. This issue is confirmed by the data provider and the exchange as of 2017-08-31. In addition, this data has an institutional recording error in exercise option style. Taiwan index options are European, while the data swaps between European and American style flags.

- Generally, there is a lack of contractual information, e.g. exercise settlement values, for most of the international index options before 2006.

2.7.4 Appendix: Figures & Tables

[25] http://www.taifex.com.tw/eng/eng2/TXO.asp

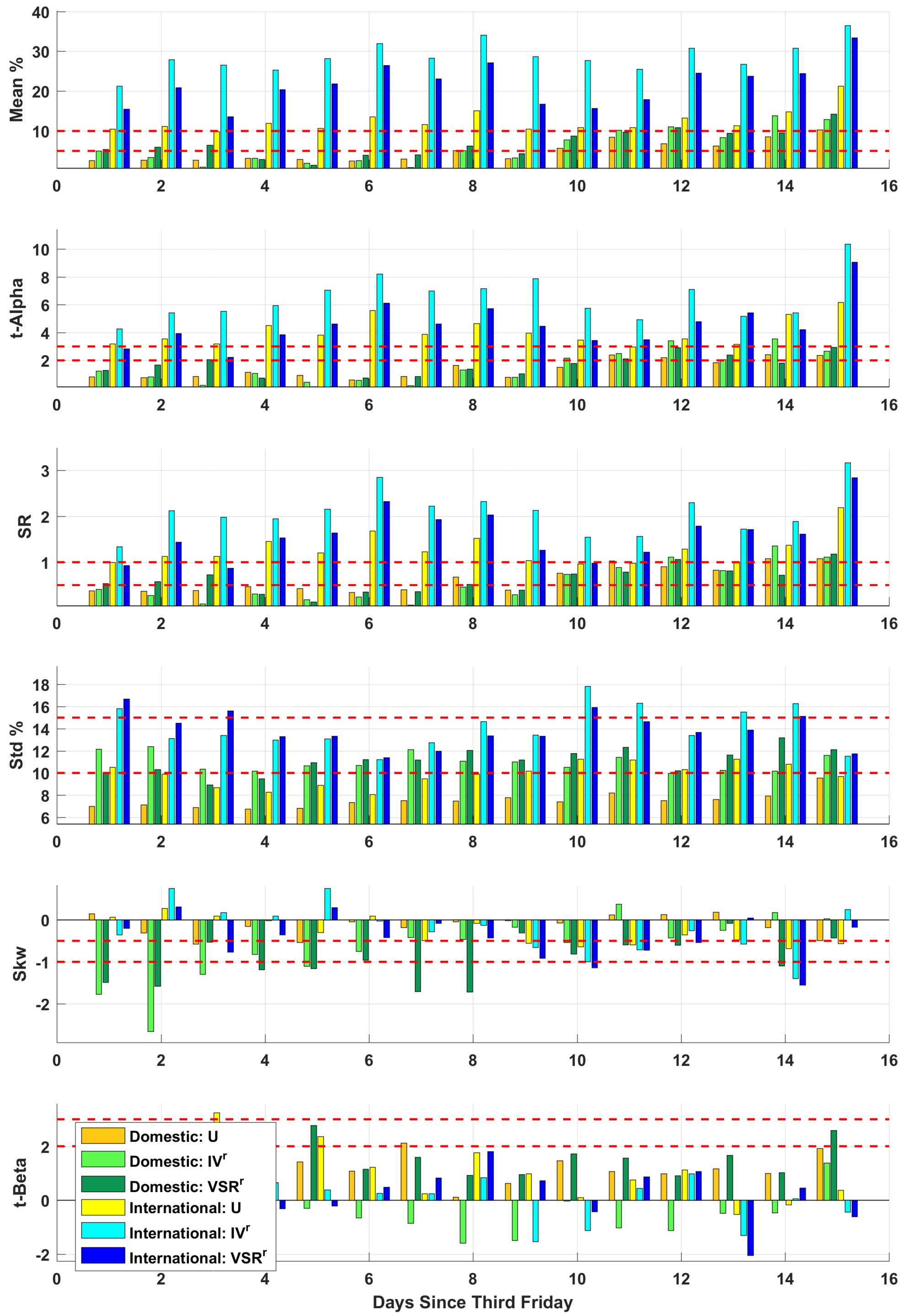

Figure 2.7.1
Dispersion Trading International and Domestic: Without Asian Indexes.

This figure investigates the time series properties of international and domestic dispersion trading option strategies without Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong index options. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and high dispersion trading portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r) ETP-index difference. Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

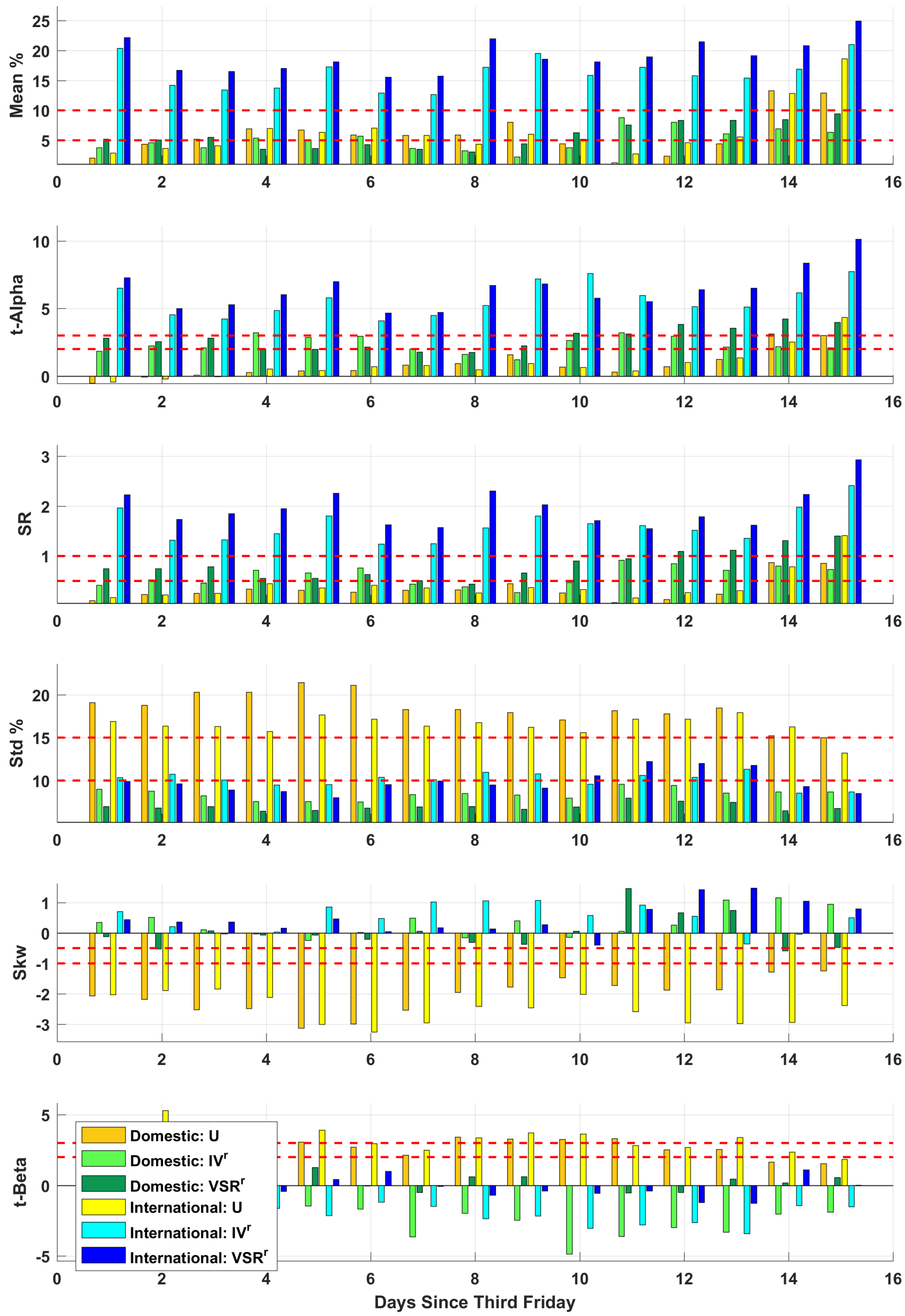

Figure 2.7.2
Cross-Section International and Domestic: Without Asian Indexes.

This figure investigates the time series properties of international and domestic option return cross-sections without Asian indexes: Korean, Japanese, Taiwanese, Australian and the Hong Kong index options. The x-axes represents the day in which portfolios are executed, which is the number of days since the last third Friday of the month. The figure reports unconditional (U) and long-short option portfolios sorted either by ex-ante implied volatility returns (IV^r) or ex-ante volatility swap rate returns (VSR^r). Ex-ante volatility returns are constructed as one minus the ratio of previous year realized volatility to time t implied volatility or volatility swap rate. Option returns are computed at mid-prices, held to maturity, denominated in US dollars and in excess of US risk-free rate. The y-axes report: annualized average return in percent (Mean), alpha t-statistic with respect to Fama and French (2015) plus Carhart (1997) factors models (t-Alpha), annualized Sharpe ratio (SR), annualized standard deviation in percent (Std), skewness (Skw) and CAPM-β t-statistic with respect to CRSP index (t-Beta). The sample period is January 2006 - December 2015.

Table 2.7.1
International Option Products.

This table reports all the international option products considered in the sample. Panel (A) displays ETP options, while panel (B) shows index options. The four columns display the foreign market, product name, start and end year of the sample. The sample period is January 2006 to December 2015.

	Market	Product	Start Year	End Year
ETP (A)				
	Australia	MSCI Australia	2007	2015
	Belgium	MSCI Belgium	2013	2015
	Brazil	MSCI Brazil	2006	2015
	Canada	MSCI Canada	2006	2015
	China	FTSA China 25	2006	2015
	EAFE	MSCI EAFE	2006	2015
	Emerging Markets	MSCI Emerging Markets	2006	2015
	France	MSCI France	2011	2015
	Germany	MSCI Germany	2006	2015
	Greece	FTSE Greece	2013	2015
	Hong Kong	MSCI Hong Kong	2006	2015
	India	MSCI India	2013	2015
	Italy	MSCI Italy	2010	2015
	Japan	MSCI Japan	2006	2015
	Korea	MSCI South Korea	2007	2015
	Malaysia	MSCI Malaysia	2007	2015
	Mexico	MSCI Mexico	2007	2015
	Netherlands	MSCI Netherlands	2013	2015
	Russia	Vectors Russia	2007	2015
	Singapore	MSCI Singapore	2009	2015
	South Africa	MSCI South Africa	2007	2015
	Spain	MSCI Spain	2007	2015
	Sweden	MSCI Sweden	2007	2015
	Switzerland	MSCI Switzerland	2008	2015
	Taiwan	MSCI Taiwan	2006	2015
	Thailand	MSCI Thailand	2014	2015
	Turkey	MSCI Turkey	2013	2015
	United Kingdom	MSCI United Kingdom	2006	2015
	United States	SPDR SP 500	2006	2015
Index (B)				
	Australia	SP ASX 200	2006	2015
	Belgium	BEL 20	2006	2015
	Canada	SP TSX 60	2007	2015
	Finland	OMXH Helsinki 25	2006	2015
	France	CAC 40	2006	2015
	Germany	DAX	2006	2015
	Hong Kong	Hang Seng	2006	2015
	Italy	FTSE MIB	2006	2015
	Japan	NIKKEI 225	2006	2015
	Korea	KOSPI 200	2006	2015
	Netherlands	AEX	2006	2015
	Spain	IBEX 35	2006	2015
	Sweden	OMXS30	2006	2015
	Switzerland	SMI	2006	2015
	Taiwan	TAIEX	2006	2015
	United Kingdom	FTSE 100	2006	2015
	United States	SP 500 - AM	2006	2015

Table 2.7.2
Domestic Option Products.

This table reports all the domestic option products considered in the sample. Panel (A) displays ETP options, while panel (B) shows index options. The three columns display product name, start and end year of the sample. The sample period is January 2006 to December 2015.

Product	Start Year	End Year
ETP (A)		
Barrons 400	2013	2015
Consumer Discretionary (XLY)	2006	2015
Consumer Staples (XLP)	2006	2015
Dow Jones	2006	2015
Energy (XLE)	2006	2015
Financials (XLF)	2006	2015
Health Care (XLV)	2006	2015
Industrials (XLI)	2006	2015
Materials (XLB)	2006	2015
NASDAQ 100	2006	2015
NYSE Composite NYA	2006	2008
NYSE U.S. 100 NYID	2006	2008
Russell 1000	2006	2015
Russell 1000 Growth	2006	2015
Russell 1000 Value	2006	2015
Russell 2000	2006	2015
Russell 2000 Growth	2006	2015
Russell 2000 Value	2006	2015
Russell 3000	2006	2015
Russell MidCap	2006	2015
Russell MidCap Growth	2006	2015
Russell MidCap Value	2006	2015
Russell Small Cap	2006	2015
SP 100 A (OEF)	2006	2015
SPDR SP 500	2006	2015
SP 500 Growth	2007	2015
SP 500 Index Fund	2006	2015
SP 500 Value	2006	2015
SP Midcap 400	2006	2015
SP Midcap 400 Growth	2006	2015
SP Midcap 400 Value	2006	2015
SP SmallCap 600	2006	2015
SP SmallCap 600 Growth	2006	2015
SP SmallCap 600 Value	2006	2015
Technology (XLK)	2006	2015
Utilities (XLU)	2006	2015
Index (B)		
AMEX Major Market Index - XMI	2006	2008
Dow Jones (DJX)	2006	2015
NASDAQ - Mini	2006	2015
NASDAQ 100	2006	2015
Russell 1000	2006	2015
Russell 1000 Growth	2006	2015
Russell 1000 Value	2006	2015
Russell 2000	2006	2015
Russell 2000 - Mini	2006	2012
SP 100 A (OEX)	2006	2015
SP 100 E (XEO)	2006	2015
SP 500 - AM	2006	2015
SP 500 - Mini	2006	2014
SP 500 - Mini (New)	2013	2015
SP Midcap 400	2006	2012
SP SmallCap 600	2006	2012

Table 2.7.3
Dispersion Trading Pairs.

This table reports all the dispersion trading pairs considered in the sample. Panel (A) shows international pairs, while panel (B) displays domestic pairs. Column one reports ETP option product, whereas column two reports the corresponding index option associated with the ETP option product. The sample period is January 2006 to December 2015.

	ETP Option Product	Index Option Product
International Pairs (A)		
	MSCI Australia	SP ASX 200
	MSCI Belgium	BEL 20
	MSCI Canada	SP TSX 60
	MSCI France	CAC 40
	MSCI Germany	DAX
	MSCI Hong Kong	Hang Seng
	MSCI Italy	FTSE MIB
	MSCI Japan	NIKKEI 225
	MSCI South Korea	KOSPI 200
	MSCI Netherlands	AEX
	MSCI Spain	IBEX 35
	MSCI Sweden	OMXS30
	MSCI Switzerland	SMI
	MSCI Taiwan	TAIEX
	MSCI United Kingdom	FTSE 100
	SPDR SP 500	SP 500 - AM
Domestic Pairs (B)		
	Consumer Discretionary (XLY)	SP 500 - AM
	Consumer Staples (XLP)	SP 500 - AM
	Dow Jones	Dow Jones (DJX)
	Energy (XLE)	SP 500 - AM
	Financials (XLF)	SP 500 - AM
	Health Care (XLV)	SP 500 - AM
	Industrials (XLI)	SP 500 - AM
	Materials (XLB)	SP 500 - AM
	NASDAQ 100	NASDAQ-100
	Russell 1000	Russell 1000
	Russell 1000 Growth	Russell 1000 Growth
	Russell 1000 Value	Russell 1000 Value
	Russell 2000	Russell 2000
	SP 100 A (OEF)	SP 100 - A (OEX)
	SPDR SP 500	SP 500 - AM
	SP Midcap 400	SP Midcap 400
	SP SmallCap 600	SP SmallCap 600
	Technology (XLK)	SP 500 - AM
	Utilities (XLU)	SP 500 - AM

Table 2.7.4

Sample Overview: Option Products.

This table reports an overview of the option products included in the sample. Column one reports the type of option product and column two reports the number of option products in the corresponding category. Panel (A) considers the total number of international options and its subgroups of ETP and index options. Panel (B) reports the same type of information as panel (A) but for the domestic sample. Lastly, Panel (C) shows the number of dispersion trading pairs for international and domestic options separately. The sample period is January 2006 to December 2015.

	Type of Option Products	Number of Option Products
International Sample (A)		
	International Options	46
	ETP	29
	Index	17
Domestic Sample (B)		
	Domestic Options	52
	ETP	36
	Index	16
Dispersion Pairs (C)		
	International Pairs	16
	Domestic Pairs	19

Chapter 3

The Timing of Option Returns

Adriano Tosi & Alexandre Ziegler[1]

Abstract

The returns from shorting out-of-the-money S&P 500 put options are concentrated in the few days preceding their expiration. Back-month options generate almost no returns, and front-month options do so only towards the end of the option cycle. The concentration of the option premium at the end of the cycle reflects changes in options' risk characteristics. Specifically, options' convexity risk increases sharply close to maturity, making them more sensitive to jumps in the underlying price. By contrast, volatility risk plays a smaller role close to maturity. Our results imply that portfolio managers wishing to harvest the put option premium should short front-month options only during the last days of the cycle, while investors wishing to protect against downside risk should use back-month options to reduce hedging costs.

Keywords: Option Returns, Out-of-The-Money Put Options, Market Timing.

JEL Classification: G11, G12, G13, G14

[1]We thank Darrell Duffie, Sergey Gelman, Michel Habib, Thorsten Hens, Egor Maslov, Steven Ongena, Walter Pohl, Hanlin Yang, participants at the Belgrade Young Economists Conference 2017 and seminar participants at the University of Zurich for valuable feedback.

3.1 Introduction

The large magnitude of index option returns is one of the major findings in empirical asset pricing and has attracted enormous interest from both academics and practitioners. Documenting and explaining these returns is the focus of a substantial body of research, and writing out-of-the-money puts is a widespread hedge fund strategy. The literature has documented and provided theoretical explanations for two main phenomena: the level of option returns and their dependence on moneyness – or, in option parlance, the overall level of implied volatility and the volatility smile or skew. Yet, little is known about *when* option returns actually accrue. Since options' payoffs at maturity are nonlinear, one would expect both their expected return and risk to depend on their time to maturity.

In this paper, we document that expected option returns are highly time-varying. Specifically, the returns from shorting out-of-the-money (OTM) S&P 500 put options are concentrated in the last few days preceding their expiration. Accordingly, shorting back-month options generates almost no returns, and shorting front-month options does so only towards the end of the option cycle. Strikingly, we find that shorting front-month OTM put options during the last week or even the last day of the option cycle earns returns that are as high as or even higher than those earned by shorting OTM put options during the entire cycle, both on a raw and on a risk-adjusted basis. For instance, during the period 1996-2015 and accounting for transaction costs, shorting front-month OTM put options four weeks before expiration and holding them to maturity generates average returns of 5.52% per year with a Sharpe ratio of 0.66, whereas shorting such options just one week before expiration (and again holding them to maturity) earns average annual returns of 8.69% with a Sharpe ratio of 2.8.[2] Even more strikingly, shorting options a single day before their expiration yields an annual return of 6.60% and a Sharpe ratio of 0.95. By contrast, shorting back-month options over the entire option cycle would have generated annual returns of merely 0.42%, with a Sharpe ratio of 0.06.

In order to obtain a precise picture of how option returns depend on their time to expiration, we compare the returns from shorting options at the beginning and at the end of the option cycle, and perform a day-by-day analysis of the return distribution. The results consistently show that shorting back-month options earns virtually no returns throughout the option cycle, while the returns from shorting front-month options are negligible up to about two weeks before expiration and rise sharply thereafter. These findings hold for both unhedged and delta-hedged returns and are robust to transaction costs.

We quantify the abnormal returns from shorting front-month options at different points in the cycle using a wide range of benchmark models comprising stock market, option, and liquidity factors. We find that shorting these options one week before maturity yields an annualized alpha between 7% and 8% with respect to all benchmark models. Shorting options over the last day of the cycle generates sizable risk-adjusted returns with respect to all benchmark models as well, with alphas ranging from 4% to 7%, an impressive value for being invested twelve days a year.

In order to determine whether these returns reflect compensation for risk or market frictions, we investigate the distribution of excess returns of front- and back-month options and their liquidity at different points of the cycle. Market frictions would affect returns, for example, if some categories of market participants with sizable net supply or demand are present only in front- or back-month

[2] All the returns presented in the paper are excess returns.

options. However, we do not find any statistically significant difference in returns when a given option series switches from being the back month to becoming the front month. By contrast, our analysis uncovers large changes in options' risk profile during the cycle. Specifically, we find that both delta and vega fall before expiration, while gamma rises sharply. Thus, jumps in the underlying's price – rather than volatility risk – constitute the main risk from shorting options close to maturity. Finally, we investigate whether the returns can be explained by options' illiquidity. Although it is often claimed that short-dated options lack liquidity, we find that front-month options are heavily traded even at the end of the cycle. Overall, our findings suggest that convexity-jump risk is the most likely cause of the large option returns in the last days of the cycle.

Our findings have important practical implications for both option writing and portfolio insurance strategies. Specifically, portfolio managers wishing to harvest the put option premium should short front-month options only during the last days of the cycle and hold them to maturity. By contrast, investors wishing to protect their equity portfolios against downside risk should purchase back-month options to reduce their hedging costs.

The article is related to three main strands of literature: the literature investigating option returns, that on the use of options for speculation or hedging, and that on seasonality in asset returns. While both option returns and seasonality in asset returns have been studied extensively, we are not aware of studies investigating option returns as a function of their time to maturity.

Most of the literature on option returns focuses on the average returns on index options and the profitability of selling volatility using various option strategies or volatility derivatives.[3,4] For instance, Coval and Shumway (2001) investigate the returns on S&P 100 and S&P 500 options for the periods 1986-1995 and 1990-1995, respectively. They find that zero-beta at-the-money straddles generate negative average returns of about 3% per week and conclude that volatility risk is priced. Jackwerth (2000) analyzes S&P 500 option returns after the 1987 crash and finds that monthly put option returns are strongly negative in risk-adjusted terms. Constantinides et al. (2009) document an increased volatility smirk of OTM options after the 1987 crash, which they view as mispricing. Bondarenko (2014) investigates monthly returns on S&P 500 futures options for the period 1987-2000. He finds that put options lose up to 95% of their value and that no model from a broad class of models is able to explain these returns, even when allowing for the possibility of a Peso problem and incorrect investor beliefs. As is already apparent from this discussion, while there is broad agreement in the literature on the large economic magnitude of index option returns, there is some debate on whether these returns represent compensation for risk, market imperfections, or behavioral anomalies.[5]

[3]The option strategies most commonly studied in the literature are writing naked and delta-hedged put options, covered call writing, and short strangle and straddle combinations.

[4]Since our analysis considers index options, our discussion focuses on this literature. There is also a literature on the cross-section of expected option returns. Key findings from this literature include the profitability of sorts on realized minus implied volatility (Goyal and Saretto (2009)) and idiosyncratic volatility (Cao and Han (2013a)), of selling out-of-the-money calls on individual stocks that do not have an ex-dividend day prior to expiration (Ni (2008)), and of purchasing straddles around earnings announcements (Xing and Zhang (2013)).

[5]Bakshi and Kapadia (2003) consider the returns on delta-hedged S&P 500 option portfolios for the period 1988-1995, which should earn the riskless rate in a Black-Scholes world. They find that the average returns on these strategies are strongly negative, supporting the existence of a negative market volatility risk premium. Using S&P 500 index futures options between 1986 and 2000, Jones (2006) finds that linear and nonlinear factor models have difficulties in explaining the economic magnitude of short-term OTM put option returns. By contrast, using monthly S&P 500 futures option returns from 1987 to 2005, Broadie et al. (2009) find that the large negative average monthly returns of OTM put options – about

A number of recent studies investigate option returns over short periods, such as overnight or during weekends. Jones and Shemesh (2018) compute option returns for index options, the cross-section of single stock options, and ETF options during the period 1996-2014. They find that option returns are significantly lower during nontrading periods, such as weekends. Using high-frequency data on S&P 500 index options, the cross-section of single stock options, and ETF options for the period 2004-2013, Muravyev and Ni (2016) find that option returns are negative overnight and positive during the day, with average values of -1% and 0.3%, respectively. Both Jones and Shemesh (2018) and Muravyev and Ni (2016) explain the effects they document by an inaccurate account of lower overnight volatility by market participants.[6]

By contrast with existing work, which typically considers returns either on a weekly (Coval and Shumway (2001)) or calendar month basis or over the entire option cycle (Broadie et al. (2009), Hodges et al. (2003)), our analysis investigates how option returns depend on their time to maturity. Our analysis complements existing research by documenting substantial differences in average option returns between front-month and back-month options – specifically, that back-month options barely earn any premium – and by showing that even for front-month options, returns accrue mainly right before expiration.[7]

Our results are also relevant to the extensive literature investigating the empirical performance of option pricing models and quantifying variance risk premia (see, for example, Bakshi et al. (1997), Eraker et al. (2003), Bakshi et al. (2003), and Christoffersen et al. (2009) for the former and Carr and Wu (2009), Amengual (2009), Bollerslev and Todorov (2011), Bardgett et al. (2019), Gruber et al. (2015), Egloff et al. (2010), and Filipović et al. (2016) for the latter) and to the literature analyzing the types of premia collected by OTM put options, which finds that jumps and jump risk premia are important to explain option prices and returns (see, for example, Bates (1996), Duffie et al. (2000), Broadie et al. (2007) and Andersen et al. (2015)). This literature has typically excluded the last six days of the option cycle from its analyses based on concerns about options' illiquidity during that period. We show below that there is actually substantial trading activity during the last days of the option cycle.[8] Our finding that option returns mostly accrue shortly before expiration suggests that it would be interesting to investigate the performance of option pricing models for very short-term options. Since we show below that the option premium shortly before expiration reflects price jump risk rather

-57% in their sample – are consistent with the Black-Scholes and Heston models. Bollen and Whaley (2004) investigate whether option prices reflect demand pressures and limits to arbitrage. Using S&P 500 options for the period 1988-2000, they find that daily changes in the implied volatility of an option series are significantly related to net buying pressure and that the changes are transitory, as market makers are gradually able to rebalance their portfolios. They also find that selling options and delta-hedging them generates large profits. Moreover, the profits are highest for OTM put options, for which there is large institutional demand for portfolio insurance. Along similar lines, Garleanu et al. (2009) show that the expensiveness of options is related to end-user demand. A number of authors relate option returns to behavioral biases. Hodges et al. (2003) investigate the relationship between moneyness and option returns using S&P 500 and FTSE 100 index futures options for the period 1985-2002. They find that deep OTM options, both puts and calls, have large negative returns, and that the relationship between option returns and moneyness is reminiscent of the favorite/long-shot bias in horse race betting. Ziegler and Ziemba (2015) show that this pattern is also present in a more recent sample that includes the 2008 financial crisis.

[6] In one of their robustness checks, Muravyev and Ni (2016) extend their analysis to short-term options, but the shortest maturity they consider is four days.

[7] While both Hodges et al. (2003) and Ziegler and Ziemba (2015) consider returns on options with a time to maturity exceeding one month, they do not distinguish between front-month and back-month options and do not investigate when the returns accrue.

[8] Moreover, CBOE Rule 8.15 obliges market makers to *"facilitate any imbalances of customer orders for SPX options (Hybrid 3.0 classes)"*. For further information on this provision, see `http://wallstreet.cch.com/cboe/rules/cboe-rules/chp_1_1/chp_1_1_8/chp_1_1_8_1/chp_1_1_8_1_15/default.asp` .

than volatility risk, incorporating price jumps in option pricing models is probably even more important for their performance at the very short end. Finally, based on the magnitude of option returns right before expiration, one would expect variance risk premia to be especially large at that time.

Another strand of literature to which our work is related is that devoted to the use of options for speculation and hedging. In spite of the differing views on the underlying causes of the magnitude of option returns discussed above, index option writing appears quite attractive to investors and is a widespread strategy among hedge funds. Indeed, Agarwal and Naik (2004) show that the returns of many hedge funds have sizable exposure to S&P 500 index put option returns and therefore exhibit large left tail risk. In order to understand whether option selling is optimal for investors, Driessen and Maenhout (2007) include index options in the standard portfolio problem. Using data on S&P 500 index future options for the period 1987-2001, they find that CRRA investors find it always optimal to short OTM puts and at-the-money straddles. The option positions are economically and statistically significant and robust to corrections for transaction costs, margin requirements, and Peso problems.[9] They find that loss-averse and disappointment-averse investors also optimally hold short option positions. Only with highly distorted probability assessments can the authors obtain positive portfolio weights for puts and straddles.

In spite of their expensiveness, index options have also been shown to be useful to protect equity portfolios against downside risk. Liu et al. (2003) find that adding options to a stock portfolio yields large improvements in certainty-equivalent wealth. Interestingly, calibrating their model to the S&P 500, they find that investors' optimal position in index put options may be positive or negative, depending on their risk aversion and how jump risk is rewarded relative to diffusive risk, with a large premium for jump risk making put option writing more likely. Filipović et al. (2016) show that investors' optimal position in put options is time-varying and depends on market conditions, with investors at times buying OTM put options to hedge market risk, and at others shorting them to harvest the volatility premium.

Our results complement this work by showing that the profitability of option writing is concentrated in the few days before option expiration and that front-month and back-month options are not equally suited for speculation and hedging. Accordingly, investors' optimal portfolio will likely depend not only on market conditions, but also on the option expiration calendar. Furthermore, an investor's optimal portfolio could simultaneously include both a short position in front-month options to earn the option premium and a long position in back-month options to hedge market risk.

The third strand of literature to which our work relates is that on seasonalities in asset returns. Return seasonalities have been documented in various asset classes and may reflect macroeconomic announcements, time-varying risk premia, or short-term illiquidity. On equity markets, they are present both at the aggregate level and in the cross-section. Lucca and Moench (2015) show that 80% of the US equity premium is concentrated in the day preceding scheduled Federal Open Market Committee (FOMC) meetings, while other macroeconomic announcements do not give rise to similar effects. Heston

[9] Santa-Clara and Saretto (2009) show that transaction costs and margin requirements can substantially reduce investors' ability to exploit the large average returns on index options. Using data on S&P 500 cash index and futures options for the period 1985-2001 and 1996-2006, respectively, they find that average monthly returns on deep OTM put options range from −50% to −60%. However, transaction costs have a substantial impact on performance, decreasing option returns by 10% per month. Furthermore, the margin requirements for writing put options imply that only 1% to 10% of an investor's wealth can be used for naked and delta-hedged short put option positions, limiting the returns that can be achieved in practice.

and Sadka (2008) document the existence of calendar month seasonality in the cross-section of stock returns. More recently, in a comprehensive analysis for the period 1963-2011, Keloharju et al. (2016) show that past winning (losing) stocks in a specific month have high (low) expected returns in the same calendar month and that a strategy that selects stocks based on their historical same calendar month past returns earns average annual returns of 13% with a Sharpe ratio of 1.67. They also find that numerous anomaly portfolios share similar calendar month patterns, as do the cross-section of country indices and commodity futures. They conclude that risk premia exhibit seasonal variations. Kamstra et al. (2015) document that Treasury returns are driven by seasonal variation in investors' risk aversion rather than macro-announcements.

Return seasonalities caused by illiquidity and limits to arbitrage are present in several asset classes. Mou (2010) investigates the behavior of commodity futures prices during rollover periods of the Goldman Sachs Commodity Index (GSCI) and finds that rollover activity by index-tracking products has a substantial price impact on both the front-month and back-month contracts, with the former exhibiting a large sell off and the latter large buying pressure. He shows that anticipating the rollover of these contracts with a calendar spread strategy would have achieved a Sharpe ratio of 4.39 over the period 2000-2010. Kang et al. (2011), among many others, document that tax-loss selling towards the end of the year can partially explain the January effect. Stivers and Sun (2013) find that average returns on the S&P 100 index and S&P 100 stocks are higher during option-expiration weeks (a month's third-Friday week) and relatively low during the following week. The annualized Sharpe ratio of S&P 100 index returns during option expiration weeks is 1.29, versus 0.06 for the other weeks. They show that option market makers' call-related delta exposure tends to decrease appreciably over the option expiration week, implying a decline in their short-stock hedge position. They conclude that delta-hedge rebalancing by option market makers likely contributes to the weekly return patterns. Using data for 1995-2013, Etula et al. (2015) show that the monthly cash needs of institutions induce systematic patterns in global stock returns. They document strong reversals in stock index returns around the last monthly trading day that guarantees cash settlement before month end and that these reversals are related to institutional trading activity, fund flows, and funding conditions.

Our work complements the literature on asset return seasonalities by showing that expected option returns also exhibit strong seasonal variation. However, by contrast with most of the literature, the return patterns that we document are related not to calendar time, but to the expiration schedule that is specific to the option market.

The remainder of the article is organized as follows. Section 3.2 describes the data used in the study. Section 3.3 exposes our methodology. Section 3.4 presents our main empirical findings. Section 3.5 concludes and discusses avenues for further research.

3.2 Data

Our analysis focuses on the returns on S&P 500 index options, which are the most liquid. The sample period ranges from January 2, 1996 to August 31, 2015, a total of 4949 trading days. The sample spans several business cycles and a number of major crises, such as the 1997 Asian financial crisis, the 1998 Russian default, the 2001 bursting of the dotcom bubble, the 2008 financial crisis, and the 2011

European debt crisis. This should mitigate concerns that the return distributions documented below are affected by a Peso problem.

The data required for our analysis includes data on S&P 500 index options, the S&P 500 cash index and futures, and data on return factors which we use to assess the abnormal returns of our option strategies. With a single exception mentioned below, all data are available for the entire sample period.

Data on S&P 500 index options (henceforth SPX options) are from the OptionMetrics IvyDB dataset. SPX options are European. From the OptionMetrics option prices file, we download daily data on all available option series. For each option series, the data includes the date of the trade or quote, a put/call flag, the expiration date, the strike price, closing bid and ask prices, the last date on which the option was traded, volume, open interest, implied volatility, and the Greeks (delta, gamma, vega, and theta).[10] From the OptionMetrics volume file, we obtain the daily aggregate volume and open interest data of SPX options, which is available for calls and puts separately.

We retain options with standard third Friday morning (AM) settlement, i.e. exclude weekly and PM-settled options. We consider the returns on the two closest monthly maturities, which we call the front-month and back-month contracts throughout. The average number of strikes available each trading day is 95 for the front month and 82 for the back month.

Our analysis also requires several data elements on the S&P 500 (SPX) cash index and futures. For portfolio construction, which requires options' moneyness, we obtain the closing index level from the Center for Research in Security Prices (CRSP) daily S&P 500 file. For performance comparison purposes, we obtain daily and monthly data on the S&P 500 total return index from the CRSP daily and monthly SPX files. For the computation of the settlement payoff at the expiration of the options, we download the SPX settlement price (SET) directly from the Chicago Board Options Exchange (CBOE) website.[11] It is important to note that this price is computed based on a special opening quotation of the S&P 500 index and its value may therefore differ significantly from the opening price of the cash index reported in common databases.[12] For the computation of delta-hedged option returns, we download daily data on the front-month S&P 500 legacy (SP) and E-mini (ES) futures contracts from Bloomberg, rolled over one day before expiration. Although the S&P 500 E-mini contract was only introduced in September 1997, it became popular very quickly and its trading volume soon exceeded that of the legacy contract. Accordingly, we use the legacy contract until the January 1998 option expiration (January 17, 1998), and the E-mini contract thereafter.

In order to quantify the abnormal returns of our option strategies, we also obtain data on a wide range of return factors from the literature including equity, option, and liquidity factors. Daily and monthly risk-free rate and returns on the Fama and French (1996) market (MKT), size (SMB), and value (HML) factors are obtained from Ken French's data library.[13] We also obtain monthly data on the momentum (UMD) factor of Asness and Frazzini (2013) and Asness et al. (2014) and the betting against beta (BAB) factor of Frazzini and Pedersen (2014) from the AQR Capital Management website.[14] In addition to

[10] OptionMetrics computes the Greeks using the Black-Scholes formula; we refer the reader to the IvyDB US reference manual for a detailed description of the procedure.

[11] The data are available at http://www.cboe.com/data/settlement.aspx.

[12] Since the CBOE provides SET data only from 17-Apr-1998 onwards, we download the index settlement prices for the early part of the sample from Bloomberg. Although they do not match perfectly, Bloomberg and CBOE data are very similar for the period where both are available. We use the CBOE data whenever available because it constitutes the official settlement values.

[13] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

[14] Data on both factors were downloaded from https://www.aqr.com/library/data-sets/

these equity-based factors, we download monthly return data on the three factors of the global asset pricing model of Asness et al. (2013), which has been claimed to be able to price all major asset classes. These factors are the return on the MSCI world equity index (MSCI) in excess of the US risk-free rate, and the value and momentum everywhere factors (VALEW and MOMEW), which are computed as the aggregate value and momentum factors across four asset classes (commodities, currencies, equities, and fixed income) and four regions (US, UK, Europe, and Japan). MSCI data are obtained from Datastream, and VALEW and MOMEW data from the AQR Capital Management website.[15]

As option factors, we use the excess returns on the CBOE Put Index and on the Agarwal and Naik (2004) option factors, which have been used extensively in hedge fund performance measurement. The CBOE Put index measures the returns of a strategy that shorts front-month S&P 500 put options against collateralized cash reserves held in a money market account.[16] The Agarwal and Naik (2004) option factors comprise four factors, Put-ATM, Put-OTM, Call-ATM, and Call-OTM. Each factor represents the excess returns over a calendar month from buying an option maturing the following month and holding it for one month. The data are obtained from a WRDS research application which provides monthly returns for the period from January 1996 to December 2014. As noted in Agarwal and Naik (2004), since option returns are much more volatile than those on other return factors, we scale them by a factor of 100. Furthermore, since our strategies involve shorting options, in our analysis we reverse the sign of the Agarwal and Naik (2004) factors so that they represent the excess return from shorting the corresponding options.

Finally, we obtain data on the traded liquidity factor of Pástor and Stambaugh (2003) from the WRDS liquidity factors monthly file.

3.3 Methodology

This section describes the methodology used to construct our option portfolios and compute their returns. All analyses are performed separately for front-month and back-month options. To fix ideas, at the beginning of March, the front-month contract is the one maturing on the third Friday of March, and the back-month contract that maturing on the third Friday of April (or on the Thursday preceding it if the Easter holiday happens to fall on the third Friday). At the end of March, the front-month contract is April, and the back-month contract is May. Figure 3.1 provides a graphical illustration of the concept.

3.3.1 Strategies Considered

We analyze the returns on three types of option strategies. The only difference between them is how long the options are held. The first strategy shorts options a certain number of days before the maturity of the front-month contract and holds front-month options to maturity, while positions in back-month options are closed at the market price prevailing on the day (typically a Thursday) preceding the expiration of

`betting-against-beta-equity-factors-monthly` as of 2016-08-01.

[15]Data on the VALEW and MOMEW factors were downloaded from `https://www.aqr.com/library/data-sets/value-and-momentum-everywhere-factors-monthly` as of 2016-08-01.

[16]Further information on the CBOE Put Index can be found at `http://www.cboe.com/micro/put/`.

the front month.[17] We use this strategy to assess how the profitability of shorting options depends on the time that the positions are entered.

The second strategy we consider is used to contrast the returns at the beginning and at the end of the cycle – for example, how the returns from shorting options during the first half of the cycle compare with those from shorting them during the second half. Like the first strategy, the second strategy shorts options a certain number of days before the expiration of the front month. Positions opened more than ten days before the expiration of the front month are closed ten days before expiration, while those opened ten or fewer days before expiration are held to maturity for the front month and closed on the Thursday preceding the front month's expiration for the back month.

The third strategy shorts options a certain number of days before the maturity of the front month and holds them for a single day. We use it to obtain a precise picture of the day-by-day variation in the return distribution.

As is apparent from this discussion, the portfolio construction methodology is identical for all three strategies, and all three strategies vary along a single dimension: the time of portfolio construction. We measure it in number of business days before the expiration of the front-month contract, using the convention that the day count relates to the first day in which the portfolio is held (with the portfolio constructed at the previous close). For example, a day count of -1 relates to a portfolio constructed at the close on Wednesday and held starting Thursday, which is one day before the expiration taking place on Friday. We chose to count the days in business days rather than actual trading days to avoid any look-ahead bias that would arise because of unexpected market closures, the prime examples of which are the ones following the September 2001 events and hurricane Sandy. However, our procedure does account for changes in option expiration dates related to holidays (the main one being that options expire on Thursday if the Easter holiday happens to fall on the third Friday of April). For expositional convenience, in the remainder of the paper we shall typically refer to the expiration day as a Friday and the day preceding it as a Thursday; however, all our analyses do make the necessary adjustments when the expiration takes place on Thursday.

3.3.2 Portfolio Construction

In order to ensure that the portfolio construction methodology can be applied in practice, we ensure that it is not subject to look-ahead bias and only the most liquid options are included in the portfolio. To prevent look-ahead bias, the information used in portfolio construction is lagged by one trading day. Only including liquid options in our portfolios is important for two reasons. First, current research on hedge fund strategies in other asset classes points out that only the most liquid securities can actually be traded (see, for example, Asness et al. (2013) and Daniel and Moskowitz (2016)). Second, part of the returns on illiquid securities might reflect an illiquidity premium (Pástor and Stambaugh (2003) and Asness et al. (2013)).[18]

On the day of portfolio construction, we screen available options using the standard procedure used the literature to avoid illiquid securities (see, for example, Driessen et al. (2009), Goyal and Saretto (2009), and Muravyev (2016)). Specifically, we exclude all the options that had a price below or equal

[17] We also investigated closing the position in back-month options on the Friday evening and the results are robust in all respects.

[18] In a separate analysis, we find that less liquid options indeed earn a larger premium.

to 0.1 USD on the previous trading day. In addition to eliminating illiquid securities, setting a minimum bid price reduces the probability of facing a zero bid price when the portfolio is built. The choice of a value of 0.1 USD is based on the fact that even if the option loses half of its value by the time the portfolio is built, shorting it would still allow collecting some premium.

After eliminating options with very low prices, we perform an explicit liquidity screening. Considering front-month and back-month options and calls and puts separately, we select the top 25% of options based on their trading volume on the previous day.[19] We have also performed the analysis selecting the top 50% of options and using open interest on the previous day instead of volume and obtained results that are similar to those reported below.

By contrast with open interest, which is only available with a one-day lag, volume data are available in real time. We nevertheless choose to use volume on the previous trading day because much of the volume in volatility-sensitive products is concentrated in the last minutes of the trading day.[20] In spite of using lagged volume, our liquidity screening is quite successful. Indeed, while about 15% of options are not traded on average, this percentage drops to 10% (3%) among the 50% (25%) of options with the most volume on the previous day.

Having performed the liquidity screening, we classify all remaining options as ATM, OTM, or ITM. Again considering the front-month and back-month contracts and puts and calls separately, the ATM option is the one with the minimum absolute difference between strike price and the SPX cash index level on the previous day. OTM put options are those options with strike below the ATM strike, and ITM put options those with strike above the ATM strike. The opposite holds for calls.

After screening for liquidity and classifying the options as ATM, ITM, and OTM using information from the previous day, we construct equally-weighted portfolios of the options in each group (front-month and back-month, puts and calls, and ATM, ITM, and OTM). Each option that met the screening criteria using information from the previous day is included in the portfolio only if it has positive volume and a nonzero bid price on the day of portfolio formation.[21] We then compute the return and the Greeks of each portfolio as the simple average of the values for its constituent options.[22] As some care must be taken when computing the returns on an individual option, we now describe the related procedure in detail.

3.3.3 Return Computations

For each day in the sample, we compute the excess return from a short position in each option included in the portfolio over the holding period corresponding to each of the three strategies. For each strategy, we keep track of two sets of returns, one assuming that all transactions are conducted at mid-prices,

[19] We screen front-month and back-month options separately because front-month options tend to be more liquid than back-month options; hence, a joint liquidity screening would mainly select front-month options. However, screening puts and calls separately is not critical. We have also performed all computations with a common screening of puts and calls and the results are similar.

[20] We also performed our analyses with screening with same-day volume and the results are robust in all regards.

[21] Arguably, this selection could cause some look-ahead bias since volume for the day is not known at that time. As noted above, however, the number of options that need to be excluded is only about 3%. Furthermore, one should remember that even though a few of the options are not traded, quotes for them are available, so that it would actually be possible to enter positions at the bid price. We have performed the computations doing so and the results are again similar to those presented below.

[22] In our discussion of the results, we also report the average implied volatility, volume, open interest, and relative bid-ask spread of the options included in each portfolio. These are computed in the same way.

and the other with all transactions conducted at bid and ask prices.

There are quite a number of cases to consider when performing these computations. First, one needs to distinguish whether one is computing mid-price returns or returns with transaction costs. Second, while all three strategies close positions in the back-month contract, positions in front-month options are held to maturity in the first strategy and for portfolios constructed during the second part of the cycle for the second strategy. The terminal value of these options is computed based on the SPX special opening quotation on the expiration date (SET). Third, a limited number of options do not trade on the day where the positions must be closed. In that case, we compute the returns on the affected options using pricing bounds obtained from the convexity of the option payoff. Appendix 3.6 provides a formal description of the different cases that can arise and the computation of the price bounds.

In addition to unhedged returns, we compute delta-hedged returns following the procedure described in Ziegler and Ziemba (2015). Consistent with industry practice, hedging is performed using futures. The hedged return is obtained as the sum of the unhedged return and the payoff from the hedge (computed as the option's delta times the change in the futures price), scaled by the initial option price. The formal computations are described in Appendix 3.6.[23] We use the delta at the time of trade entry in our computations. This should not cause any material look-ahead bias for two reasons. First, deltas can be easily computed using the Black-Scholes model a few minutes before the end of trading day and are provided in real-time by data vendors. Second, they can be approximated model-free and with minimal computational burden from the cross-section of put option prices using $\frac{P_2-P_1}{K_2-K_1}$, where P_1 and K_1 denote the price and strike of the put option for which one seeks to compute delta, and P_2 and K_2 the price and strike of an adjacent put option.[24]

Having obtained the returns from a short position in each option over the holding period corresponding to each strategy, we convert them to excess returns by adding the riskless rate to the option return. Finally, as is typical in studies of option returns (see, for example, Agarwal and Naik (2004) and Santa-Clara and Saretto (2009)), we scale all excess returns by a factor of 100. Accordingly, the returns we report correspond to the excess returns achieved by taking a short position of 1% of wealth in OTM options, and the maximum excess return of all strategies is 1%.

The above procedure is performed for each trading day in our dataset. In our sample, the beginning of the first cycle for which we have complete data is January 17, 1996, and the end of the last complete cycle is August 20, 2015, a total of 235 complete cycles. In order to have an identical sample period for all three strategies, we discard the returns corresponding to portfolios constructed before the beginning of the first complete cycle or after the end of the last one. The results are virtually identical if these extra few days are included.

3.4 Empirical Findings

This section presents the empirical evidence that the OTM put option premium is concentrated in the last days of the option cycle. We begin in Section 3.4.1 by reporting a few striking facts about the

[23] Since SPX futures are extremely liquid and have extremely narrow spreads of 1-2 bps, we neglect the transaction costs from trading futures.

[24] This heuristic approximation can certainly be improved on but has the advantage of being extremely fast to compute. We performed the analysis using deltas computed using this approximation and the results are similar to those obtained using the Black-Scholes deltas provided by OptionMetrics.

returns from shorting front-month options. We then use the three strategies presented in Section 3.3 to document strong variation in options' return distribution as a function of their time to maturity. In Section 3.4.2, we consider the first strategy and investigate the returns from opening short option positions at different points in the cycle and holding them until the maturity of the front month. In Section 3.4.3, we use the second strategy to contrast the returns from shorting options during the first half of the cycle with those during the second half. In Section 3.4.4, we use the third strategy, which holds options for a single day, to assess the day-by-day variation in options' return distribution. Section 3.4.5 analyzes the potential sources of the return patterns that we document. Section 3.4.6 discusses the robustness of our results and provides a short overview of our findings for other types of options.

3.4.1 A Few Striking Facts

Figure 3.3 reports the cumulative excess returns of the S&P 500 total return index (denoted SPX), the CBOE Put index (denoted PUT), and our implementation of the Put index trading at the close of each trading day and accounting for transaction costs (i.e. selling ATM options at the end-of-day bid price; that series is denoted PUT_{ba}).[25] In addition, the figure reports the cumulative returns achieved by shorting front-month OTM put option portfolios for the last day of the monthly option cycle and holding the position to maturity, also accounting for transaction costs. The option positions are entered at the bid price prevailing at the close of the market on the penultimate day of the option cycle (usually a Wednesday since options expire at the open on Friday) and their final settlement price is computed using the SPX special opening quotation (SET). The striking result in Figure 3.3 is that one can earn the entire put option premium by being exposed only a single day per month. The results also show, however, that while the strategy of shorting options during the last day of the cycle earns large returns, it is associated with rare but steep drawdowns.

Figure 3.4 provides further evidence that the profitability of shorting options is stronger towards the end of the cycle. In addition to the returns on the benchmark indices presented in Figure 3.3, the figure reports the cumulative excess returns achieved by shorting portfolios of front-month OTM put options 4, 3, 2, and 1 weeks before expiration and holding them to maturity. In each case, the positions are entered at the bid price prevailing at the close of the market on Friday and the options' final settlement price is again computed using the SPX special opening quotation. Observe that the later the position is entered, the higher the profitability of the strategy. Thus, shorting options close to maturity allows collecting as much and perhaps more premium than by being short all the time, while keeping capital available to be deployed elsewhere.

Table 3.1 presents the main performance statistics for the three benchmark indices SPX, PUT, and PUT_{ba}, as well as for the different strategies discussed in Figures 3.3 and 3.4. The table reports average excess returns, their standard deviation, Sharpe ratio (SR), skewness, kurtosis, worst and best return, the alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, and first-order return autocorrelation ρ. Average returns, standard deviations, and alphas are in percent per year, and Sharpe ratios are annualized.

The results for the benchmark indices reported in the top panel show that consistent with the findings in the literature, shorting options yields sizable returns that are on average comparable to

[25] The CBOE Put index returns are based on transactions conducted at the volume weighted average price during the half-hour period beginning at 11:30 a.m. ET.

index returns but have lower volatility and more negative skewness. Panel B reports unhedged returns from shorting OTM put option portfolios 4, 3, 2, 1 weeks and 1 day before maturity and holding the position to expiration. Shorting options towards the end of the cycle tends to be more attractive than doing so during the entire cycle. For instance, shorting OTM puts four weeks before maturity yields average annualized returns of 5.52% with a Sharpe ratio of 0.66, whereas shorting them during the last week only yields an average annualized return of 8.69% with a Sharpe ratio of 2.8.

The returns from shorting options towards the end of the cycle are also more attractive than those of the benchmark indices. For instance, shorting options one week before maturity yields an annualized return of 8.69% compared to 5.58% for the SPX index and 6.14% for the PUT index. Even more strikingly, shorting options over the last day, i.e. being exposed only 12 days per year, yields an annualized return of 6.60% and a Sharpe ratio of 0.95. The strategies' alphas and their t-statistics also tend to increase towards the end of the cycle – being exposed for four weeks yields an alpha of 3.82%, while being exposed only for the last week of the option cycle generates an alpha of 7.93%.

Admittedly, the strategies are subject to large downside risk. However, it is worth noting that while the skewness of the return distributions exceeds those of the benchmark indices, this is caused by the fact that returns are bounded from above and have lower standard deviations than those of the benchmark indices. The worst returns of the different strategies are actually comparable to those of the benchmark indices.

Panel C in Table 3.1 presents the returns from shorting options at the beginning of the cycle and closing the position before maturity; these can be seen as the complements of the strategies in Panel B. The differences in returns compared to Panel B are striking. To take an example, shorting options from four weeks to maturity to three weeks to maturity loses 1.66% per year, while shorting options three weeks to maturity and holding them to expiration earns 6.14% per year on average. Put differently, there is basically no premium to be earned during the first week of the option cycle. Similarly, shorting options from four weeks to maturity to two weeks to maturity earns an annualized average return of only 0.62% while shorting options for the last two weeks of the cycle earns an average annualized return of 8.04%. Finally, being invested during the first three weeks of the cycle yields 2.27% a year while the last week earns an annualized return of 8.69%. These results once again show that the returns from shorting options are mostly earned in the few days before maturity.

Panels D and E present the returns of strategies with the same entry and exit times as those in Panels B and C but with delta-hedging. The return patterns are similar to those in Panels B and C: the returns from shorting options in the second half of the cycle are as large as those from shorting options during the entire cycle, and virtually no return is earned from shorting options at the beginning of the cycle. We investigate the difference in returns between the beginning and the end of the cycle in more detail in Section 3.4.3 below.

3.4.2 Returns from Shorting Options At Different Points in the Cycle

In this section we refine the analysis in the previous section by investigating the distribution of returns achieved by shorting options at different points in the cycle and holding them until the maturity of the front-month contract. We then quantify the abnormal returns earned from doing so using a wide range of benchmark models.

3.4.2.1 Return Distributions

Figure 3.5 and Table 3.2 report information on the return distribution of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. To begin with, we present results assuming that all transactions are conducted at mid-prices; results accounting for transaction costs are discussed below. We choose to focus on the case without transaction costs in order to put the front- and back-month contracts on equal footing (positions in the back-month contract would incur transaction costs twice while those in the front month would incur them only once).

The return reported for the nth day before maturity is that achieved by shorting an option portfolio at the close of the $n + 1$th day to maturity and holding it until the expiration of the front-month contract. The value of front-month options at the end of the holding period is their final settlement price, while positions in back-month options are covered at the mid price at the close of the market on the day preceding the expiration of the front month (typically a Thursday). For example, the return three days to maturity corresponds to that of a position opened at the close of the Monday and closed at the close of the Thursday preceding the option's expiration on Friday morning. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. For better readability, Figure 3.5 only reports the results for option portfolios that are not delta-hedged, while Table 3.2 reports delta-hedged returns in addition to the unhedged ones. Our discussion focuses on the unhedged returns presented in Figure 3.5; we briefly discuss the properties of hedged returns at the end of this section.

The first key observation from the results in Figure 3.5 is that while shorting front-month options generates sizable returns, those from back-month options are almost zero. Front-month options do have more risk – standard deviation, negative skewness, and the worst return are all larger than those of back-month options. Nevertheless, their risk-adjusted returns (both Sharpe ratio and alpha) are much larger. Strikingly, average returns from shorting front-month options are very similar if options are shorted during the entire cycle or only on the last day, while the standard deviation of returns is somewhat smaller. This translates to higher Sharpe ratios and alphas for positions opened towards the end of the cycle than for those held during the entire cycle. While Sharpe ratio estimates are somewhat bumpy, it is clear from Figure 3.5 that they are higher for positions opened during the second half of the cycle than for positions opened during the first half. Alpha estimates are somewhat more stable and reveal a relatively steady increase during the cycle. Considering the exact numerical values of the return distribution in Table 3.2, shorting front-month options over the full cycle earns average returns of 6.14%, a Sharpe ratio of 0.83, and an alpha of 4.63%, while shorting such options during the last five days of the cycle earns average returns of 8.14%, a Sharpe ratio of 1.83, and an alpha of 7.15%. Even more strikingly, shorting options during the last day earns average returns of 7.52% a year and a Sharpe ratio of 1.39.

The pattern of the return standard deviation for front-month option portfolios in Figure 3.5 warrants some discussion. Observe that starting from a relatively high level of about 10%, the standard deviation decreases to less than 5% for positions opened four to five days before maturity, and then increases during the last few days. Two opposing effects drive this pattern. As the options' remaining life shortens, the uncertainty about their final payoff decreases, which tends to decrease the strategy's volatility. At the same time, OTM options become less valuable, increasing the number of options that must be sold. In the last few days, the number of options shorted becomes so large that the strategy's overall volatility increases.

Table 3.2 also reports hedged returns in addition to the unhedged ones. Although expected returns, standard deviations, and Sharpe ratios all tend to be somewhat lower than for unhedged returns, the patterns over the option cycle are quite similar. Delta hedging leads to a sizable improvement in both skewness and the worst return throughout the cycle; nevertheless, both remain strongly negative.

Figure 3.6 and Table 3.3 summarize the return distributions when accounting for transaction costs. All purchases are conducted at ask prices and all sales at bid prices. As mentioned above, accounting for transaction costs has a stronger negative impact on returns for strategies using the back month than for those using the front month. As can be seen in the top panel of Figure 3.6, the average return from shorting back-month options is at best zero and even negative over the second half of the cycle. Apart from the lower returns, the patterns of the different return statistics are quite similar to those without transaction costs. In particular, Sharpe ratios and alphas for the front-month contract tend to be higher in the second half of the cycle.

3.4.2.2 Factor Exposures and Abnormal Returns

In order to gather further insights on the risk profile and abnormal returns from shorting front-month options at different points in the cycle, we run time series regressions of option excess returns on common return drivers documented in the empirical asset pricing literature. We consider shorting front-month options over the last two weeks of the cycle, over the last week, and over the last day. The results are reported in Tables 3.4, 3.5, and 3.6, respectively.[26]

All regressions are estimated using monthly returns over our entire sample period. For each option strategy and each benchmark model, we report factor exposures as well as annualized alphas in percentage points. The different benchmark models that we consider are:

1. A US equity model comprising the US market (MKT), size (SMB), value (HML), momentum (UMD), and betting-against-beta (BAB) factors for US equities obtained from Fama and French (1996) and Frazzini and Pedersen (2014).

2. The global asset pricing model from Asness et al. (2013) comprising the MSCI world index and the value everywhere (VALEW) and momentum everywhere (MOMEW) factors.

3. A model targeting liquidity exposure using, in addition to the equity return factors from Model (1), the traded liquidity factor of Pástor and Stambaugh (2003).[27]

4. Several models including the option-based factors Put-ATM, Put-OTM, Call-ATM, and Call-OTM from Agarwal and Naik (2004), representing the excess returns from shorting options on a calendar month basis. We only include one of these factors at a time because their returns are

[26] For weekly and biweekly returns, the positions are opened at the close of the market on the Friday one or two weeks before expiration, respectively. If the Friday in question is a holiday, we enter the position on the following day, ruling out any look-ahead bias.

[27] We also tested other liquidity measures, namely Pástor and Stambaugh (2003) innovations and the TED spread as defined in Asness et al. (2013) (i.e. the difference between the 3-month LIBOR and the 3-month Tbill taken from Federal Reserve Bank Reports at daily frequency and averaged geometrically over the month). The returns on our option portfolios do not have a significant exposure to these two factors.

highly correlated; furthermore, we do not include the market return because of the high correlation between option returns and the returns on the underlying index.

5. A model including the excess return on the CBOE Put index.

6. A model including the excess return from shorting a portfolio of front-month OTM put options 20 trading days before maturity and holding it until the final settlement (this is simply the return from our first strategy with an entry point of -20 days).

We first discuss the results for the strategy of shorting OTM put options one week before maturity; we contrast them with the returns earned by shorting options for two weeks or a single day below. The results in Table 3.5 reveal that shorting options one week to maturity yields an annualized alpha between 7% and 8% with respect to all benchmark models. As one would expect, shorting OTM put options has positive exposure to equity index returns, both at the US and global level. Option selling returns also have positive exposure to the value factor, reflecting the fact that value stocks tend to crash during market turbulence. Finally, as one would expect, option selling returns have positive exposure to the Agarwal and Naik (2004) put factors and negative exposure to their call factors. Importantly, while these factors do identify the nature of our strategy, they cannot account for the high level of the excess returns that it achieves. The same holds for the CBOE put index and a strategy of shorting OTM put options 20 trading days before maturity: the returns achieved during the last week load positively on both these factors, but a sizable alpha remains.

An analysis of the factor exposures and abnormal returns from shorting OTM puts during the last two weeks of the cycle reveals a similar picture. As can be seen in Table 3.4, the magnitude of the alphas is similar to those from shorting options during a single week from Table 3.5. In terms of factor exposures, the main difference is that the exposure to the value factor is no longer significant.

Turning to the returns from shorting options over the last day of the cycle only (see Table 3.6), the factor exposures are again similar to those in Table 3.5 except that exposures to the value factor are no longer significant. This strategy also generates sizable risk adjusted returns with respect to all benchmark models, with alphas ranging from 4% to 7%, an impressive value for being invested twelve days a year.[28]

3.4.3 Beginning- and End-of-Cycle Returns

Based on our finding in Sections 3.4.1 and 3.4.2 that shorting options towards the end of the cycle is as profitable as shorting them during the entire cycle, one would expect little premium to be earned from shorting options at the beginning of the cycle. Table 3.1 provided support for this intuition. In this section, we establish this fact formally by contrasting the returns from shorting options during the first half of the cycle with those earned during the second half. This comparison also allows gaining a better understanding of the nature of the risks from shorting options at the beginning and at the end of the cycle.

Figure 3.7 and Table 3.7 report information on the return distribution of portfolios of front-month and back-month options as a function of the point during the cycle that the positions are opened.

[28] For completeness, we also investigated the risk profile and abnormal returns from shorting front-month OTM puts 20 days before maturity. As one would expect, the strategy earns significant abnormal returns with respect to the various equity models, but not with respect to the Put index.

Positions opened between 20 and 11 trading days before maturity are closed ten days before maturity, while positions opened between ten days and one day before maturity are held until maturity for front-month options and closed on the evening preceding the expiration of the front month (generally a Thursday) for back-month options. The results are presented in the same format as in Figure 3.5 and Table 3.2. All transactions are assumed to be conducted at mid-prices; results accounting for transaction costs are discussed below.

The main result of this section is immediately apparent in Figure 3.7: shorting front-month options hardly earns any premium during the first half of the cycle, while the returns during the second half of the cycle are sizable. While shorting front-month options during the second half of the cycle is riskier than doing so during the first half in terms of standard deviation, negative skewness, and the worst return, risk-adjusted returns as measured by the Sharpe ratio and alpha are virtually zero over the first half of the cycle and sizable during the second half. Interestingly, only slight differences in returns between the beginning and the end of the cycle are apparent for back-month options. The patterns are similar to those for front-month options but much less pronounced. Thus, the premium that can be earned from shorting options appears to be mostly earned from holding them to maturity and bearing the risk of ending in-the-money. Closing positions before maturity alleviates much of that risk, but also erodes most of the returns.

As could be expected from the findings in Section 3.4.2.1, Figure 3.7 shows that the front month earns more premium than the back month both in the first and in the second half of the cycle. While the difference in average returns between the two contracts is small during the first half of the cycle, it is extremely large during the second half. Unsurprisingly, shorting front-month options is also riskier than shorting back-month options both in the first half and in the second half of the cycle. This is true for all risk measures considered in our analysis, namely return standard deviation, skewness, and the worst return. As was the case for average returns, differences in risk between the front month and the back month are more pronounced in the second half of the cycle. Nevertheless, the difference in risk-adjusted returns (both Sharpe ratio and alpha) between the front month and the back month mirrors that for average returns: it is small during the first half of the cycle, and large during the second half.

Figure 3.7 reveals a few additional important facts about the evolution of the risk of shorting front-month options during the cycle. First, the standard deviation of being short over the last day exceeds that of being short from 20 days to ten days to maturity (from Table 3.7, the exact values are 5.39% and 4.14%, respectively). Similarly, with a value of −14.42%, the worst return over the last day is lower than the worst return from 20 days to ten days to maturity, −11.49%. This once again shows that while the returns at the end of the cycle are attractive, there is a sizable increase in risk, limiting investors' ability to exploit them.

Figure 3.8 and Table 3.8 report the results of the same strategies as in Figure 3.7 and Table 3.7 but accounting for transaction costs. Again, all purchases are conducted at ask prices and all sales at bid prices. As can be seen in Figure 3.8, the difference in the profitability of shorting front-month options between the first and the second half of the cycle is robust to accounting for transaction costs. In fact, the difference between the first and the second half of the cycle is even stronger than when using mid-prices, reflecting the fact that shorting options during the first half of the cycle involves two transactions. Importantly, shorting front-month options during the second half of the cycle remains quite profitable, with returns that are only slightly lower than those in Figure 3.7. Transaction costs make shorting back-month options during both the first and the second half of the cycle unprofitable. Transaction costs also lead to a deterioration of the worst returns, reflecting the widening of spreads in market crashes.

3.4.4 Daily Return Patterns

In this section, we use OTM option portfolios held for a single trading day to assess the day-by-day variation of the distribution of option returns during the cycle. Since transaction costs might obfuscate the return patterns over such short periods, we conduct the analysis using mid-prices.

Figure 3.9 and Table 3.9 report information on the return distribution of portfolios of front-month and back-month options as a function of the number of days to expiration for the front-month contract.[29] The return for the nth day before maturity is that achieved by shorting an OTM option portfolio at the close of the $n + 1$th day to maturity and closing the position at the close of the nth day before maturity. For example, the return one day to maturity corresponds to that of a position opened at the close of the Wednesday and covered at the close of the Thursday preceding the option's expiration on Friday morning. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio and alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. For better readability, Figure 3.9 only reports the results for option portfolios that are not delta-hedged, while Table 3.9 reports delta-hedged returns in addition to the unhedged ones. Our discussion focuses on the unhedged returns presented in Figure 3.9; we briefly discuss the properties of hedged returns at the end of this section.

A few key facts are immediately apparent in Figure 3.9. First, the front-month contract has both higher average returns and higher risk (standard deviation, negative skewness, and worst return) than the back month throughout the cycle. While this suggests that risk accounts for the difference in returns between the front and the back month, it is worth noting that risk-adjusted returns as measured by both the Sharpe ratio and alpha are higher for the front month than for the back month. Second, for the front-month contract, the risk and return measures evolve during the cycle, indicating that there is a change in the contract's behavior close to maturity. By contrast, the risk and return measures are much more stable during the cycle for the back month.

Turning to the return patterns over the cycle, Figure 3.9 reveals that average returns from shorting OTM options increase towards the end of the cycle for the front-month contract, whereas the back month does not show any substantial increase. The alpha exhibits a similar pattern: the front month has substantial abnormal returns towards the end of the cycle, while the back month does not generate any significant risk-adjusted returns throughout.

To some extent, the increase in average returns earned by shorting the front-month contract reflect an increase in the risk of doing so. The closer one gets to expiration, the higher the standard deviation of returns, the more negative the skewness, and the lower the worst return from being short the front-month contract. By contrast, no increase in these risk measures is apparent for the back month. In spite of the higher return variability, the Sharpe ratio from being short the front month tends to increase towards maturity.

[29]For ease of explanation in Figure 3.9 and Table 3.9 we assign to day 2007-02-27 which is 13 days to expiration the average value of the distribution. This does not affect the results of any of the other tables or figures in this paper.

The daily patterns of delta-hedged returns during the option cycle are quite similar to the unhedged ones. As can be seen in Table 3.9, average returns and return volatility increase towards the end of the option cycle, as does alpha. The patterns for alpha are identical to those for unhedged returns, reflecting the fact that controlling unhedged returns for market risk essentially amounts to hedging returns with the average delta during the sample period. Delta hedging achieves a sizable improvement in both skewness and the worst return at the end of the cycle; nevertheless, both remain strongly negative.

3.4.5 Assessing the Source of the Returns

Our finding of large returns from shorting front-month options at the end of the cycle raises the obvious question of their source. In this section, we investigate whether the returns reflect compensation for risk or a market friction. We begin by taking a closer look at the distribution of excess returns of front- and back-month option portfolios at different points of the cycle. We then investigate the role of macroeconomic announcements and the contracts' risk and liquidity.

3.4.5.1 Where are Returns Concentrated?

Figure 3.10 reports non-parametric kernel density estimates of the portfolios' one-day excess returns at different points in the cycle. Each panel in the figure reports two distributions as well as the p-values of non-parametric two-sample Kolmogorov-Smirnov tests that they are identical. Panel A contrasts the return distribution of the front month 20 days to maturity with that one day before maturity. There is a substantial economic and statistical difference between the two distributions: most of the probability mass of the returns one day before maturity lies to the right of that 20 days before maturity. However, large negative returns are more frequent one day before maturity than 20 days before maturity. Panel B performs a similar comparison for the back month. The returns on back-month options one day before the maturity of the front month do appear slightly more attractive than those 20 days before expiration, but the difference is much less striking than in Panel A and its economic significance questionable.

Together, the results in Panels A and B show that the distribution of excess returns for both the front and back months differs between the beginning and the end of the cycle, but that the difference is much more pronounced for the front month. Although our sample includes 20 years of data, one might wonder whether the apparent attractiveness of short option returns at the end of the cycle reflects peculiar market events that happen to have occurred close to option expiration. To alleviate this concern, in Panel C we contrast the return distributions of both contracts on the day preceding the expiration of the front month. The difference between the two distributions is striking: while returns for the back month appear centered around zero, the returns from shorting the front month are overwhelmingly positive. Thus, there appears to be something specific about returns on front-month options close to expiration.

One might also wonder whether the returns are caused by market frictions. For instance, if some categories of market participants are present only in the front- or back-month contracts and are systematically net long or short, equilibrium expected returns would be affected. In order to assess whether this is likely to be the case, Panel D contrasts the return distributions of the back month one day before the expiration of the front month with those of the front month 20 days before expiration; in a typical month, this will correspond to the first day that the contract is the front month. Observe that while optically there are slight differences between both distributions, they are not statistically significant, with a Kolmogorov-Smirnov p-value of 72%. Thus, the mere fact that a given option contract switches from being the back month to becoming the front month does not affect its return distribution. Accordingly, the returns on the front-month contract do not appear to be caused by the fact that some categories of investors are predominantly present in the front or back month.

3.4.5.2 Macroeconomic Announcements

We saw in Panel C of Figure 3.10 that the large returns from shorting options close to expiration are only present in front-month options. While this finding suggests that these returns reflect features specific to front-month options, the possibility remains that peculiar market events that occurred at the end of the cycle affected front-month options much more strongly than back-month options. In this section, we investigate whether our return patterns reflect a risk premium associated with macroeconomic announcements.

A prime candidate for such announcements are Federal Open Market Committee (FOMC) meetings. Lucca and Moench (2015) show that 80% of the US equity premium is concentrated in the day preceding scheduled FOMC meetings, while other macroeconomic announcements do not give rise to similar effects. Since 1994 there have been eight scheduled FOMC meetings per year. These meetings usually take place on a Tuesday and/or Wednesday, and their dates are published well in advance. Importantly, a number of these meetings take place during the week of option expiration.[30]

In order to assess whether our return patterns could be driven by FOMC meetings, we collect the meeting dates from Bloomberg and cross-check them with the dates reported on the Federal Reserve Board's website.[31] We then identify the months during our sample period for which a FOMC meeting took place between the second and the third Friday of the month, i.e. less than one week before option expiration.

We then repeat our analysis excluding the 41 months in question. The return patterns over the cycle are similar to those presented above. The factor exposures and abnormal returns from shorting OTM put options two weeks, one week, and one day before the maturity of the front month (obtained by repeating the analysis in Section 3.4.2.2 for the subsample of months without FOMC meetings during expiration week) are reported in Tables 3.10, 3.11 and 3.12, respectively. The factor exposures and abnormal returns are similar to those for the full sample (Tables 3.4, 3.5, and 3.6 in Section 3.4.2.2) not just qualitatively, but also quantitatively. As was the case in Section 3.4.2.2, the alphas from shorting options two weeks and one week before maturity are statistically significant at the 1% level with respect to all benchmark models (see Tables 3.10 and 3.11), while those from shorting options one day before maturity are statistically significant at the 5% level or higher (see Table 3.12). Thus, our findings are not driven by the timing of FOMC meetings.

[30] Besides FOMC meetings, two other macroeconomic announcements strongly affect equity markets: the GDP and non-farm payroll releases. With a few exceptions, non-farm payroll numbers are announced on the first Friday of each month, i.e. two weeks before option expiration, and therefore cannot account for option returns close to expiration. Although GDP figures are quarterly, GDP announcements actually occur each month: an advanced estimate is released on the last Friday of the first month of the following quarter, and a second and third estimate are published on the last Friday of the second and third month of the following quarter, respectively. Here again, since the releases occur one week after option expiration, they cannot account for the returns just before expiration.

[31] The meeting dates can be found at `https://www.federalreserve.gov/monetarypolicy/fomccalendars.htm`.

3.4.5.3 Behavior in Crisis Periods

Our results so far suggest that the returns of front-month options close to expiration are not driven by market frictions and rather reflect compensation for their risks. Since these returns are only present in the front month and are concentrated right before expiration, one would expect to observe a difference in behavior between the front and back months close to expiration but not at other times in the cycle. In order to assess whether this is intuition is borne out in the data, Figure 3.11 reports the time-series of the returns of portfolios of front-month and back-month options at two key points in the cycle. Specifically, Panel A reports the returns 20 days before the expiration of the front month, while Panel B shows those one day before maturity.[32] To improve readability, we reverse the sign of the returns on back-month options (i.e. the figure depicts the returns on back-month options as if they were held long).

The change in the risk characteristics of front-month options close to maturity is readily apparent by comparing both panels. Early in the cycle, the behavior of both contracts is rather similar: spikes or drawdowns for both contracts coincide rather well in time and are of comparable magnitude, with the largest values reaching about 1% for the back month and 1.5% for the front month. By contrast, Panel B reveals that the behavior of the two contracts is very different at the end of the cycle, with large drawdowns in the front month not coinciding with spikes of similar magnitude in the back month. To take the most extreme example, being short the front month yields a drawdown of close to 10% late 2011, while being long the back month yields a gain of less than 2%. Thus, the riskiness of the two contracts changes during the cycle, with the front month becoming riskier relative to the back month at the end of the cycle. The results in Panel B also show that the one-day returns on the front month right before maturity exhibit the pattern that one would typically expect for a short option position: small gains most of the time, with a couple of steep drawdowns. This pattern is much less clear in the returns 20 days to expiration in Panel A.

3.4.5.4 Risk Characteristics during the Cycle

In order to gain further insights into the change in options' riskiness during the cycle, Figure 3.12 and Table 3.13 report the average implied volatility and Greeks of the option portfolios as a function of the number of days to expiration of the front month. All Greeks are reported in absolute value. Gamma is multiplied by one thousand to improve readability, theta is reported in dollars per day, and vega represents the dollar change in the option price for a one percentage change in implied volatility.

A few striking facts are apparent in Figure 3.12. First, while the implied volatility of back-month options is roughly constant over the cycle, that of front-month options increases sharply over the last week of the cycle, from about 27% four days before maturity to 40% one day before maturity, a level that is comparable to market volatility during crisis periods. While the high level of implied volatility compared to realized volatility has been documented for options at large, the increase in the few days before expiration (which is not accompanied by a comparable increase in realized volatility) reflects the effect documented in this paper that front-month options are richly priced before expiration. This is also reflected in theta, which is roughly constant over the cycle for back-month options but rises sharply at the end of the cycle for front-month options. Thus, absent shocks, front-month options lose a lot of value towards the end of the cycle.

[32] These returns are those underlying the distributions reported earlier in Figure 3.10. For instance, the distributions in Panel A (B) of Figure 3.10 are obtained from those for front-month (back-month) options in the two panels of Figure 3.11.

While the results for implied volatility and theta indicate that selling front-month options at the end of the cycle is quite attractive, Figure 3.12 also highlights that the nature of the risks to which option selling is exposed changes during the cycle. In particular, both delta and vega fall before expiration, while gamma rises sharply. Thus, jumps in the underlying's price – rather than volatility risk – constitute the main risk from shorting options close to maturity. Intuitively, the risk from shorting OTM put options close to expiration is that of a drop in the underlying which causes them to expire in-the-money. Changes in asset return volatility are much less important due to the limited time that this volatility can play out. Overall, these results suggest that convexity-jump risk is the most likely cause of the large option returns in the last days of the cycle.

3.4.5.5 Liquidity

Another potential explanation for the returns that we document could be that they reflect a liquidity premium. Indeed, it is often claimed that short-dated options lack liquidity. To alleviate this concern, Figure 3.13 and Table 3.14 report a number of liquidity measures of our OTM option portfolios over the sample period. The top two panels report the average daily volume and open interest of the strikes included in the portfolios in thousands of contracts. The next two panels report the aggregate volume and open interest of all strikes included in the portfolios, again in thousands of contracts. The last panel reports the percentage bid-ask spread relative to the mid-price.

Figure 3.13 shows that for front-month options, the aggregate volume of the options included in the portfolio is similar at the beginning and at the end of the cycle. For instance, at the beginning of the cycle, daily aggregate volume is 68 thousand contracts, against 69 thousand contracts on the last day. As can be seen in the top panel of Figure 3.13, on a per-strike basis, volume even increases. For the back month, trading volume increases during the cycle both at the aggregate level and on a per-strike basis.

Over the course of the cycle, aggregate open interest decreases for the front month and increases for the back month. This is not surprising and simply reflects the fact that investors increasingly use the back month as its maturity shortens, and some positions are rolled over from the front month to the back month over time. Interestingly, aggregate open interest in the front month at the end of the cycle (338 thousand contracts) is similar to that for the back month at the beginning of the cycle (312 thousand contracts). The percentage bid-ask spread increases during the cycle for the front month. However, this reflects the fact that mid-prices go down over time on average rather than an increase in the absolute magnitude of spreads. Thus, overall, the front month appears to have good liquidity even at the end of the cycle, suggesting that its returns are not driven by illiquidity, but rather by jump-convexity risk as discussed earlier.

3.4.5.6 Liquidity Risk

A related but distinct possibility is that the option return patterns that we document are driven by liquidity risk. Under this view, option sellers would require an additional premium not because options are generally illiquid right before expiration, but because the *risk* of not being able to close out positions increases close to expiration. To gauge this possibility, Figure 3.14 and Table 3.15 report several measures of this risk. We consider three sets of measures and for each, report the average and standard deviation in our option portfolios. The first is the extent to which trading volume for a particular option contract drops between two consecutive days. The second relates option volume to open interest on the previous day. The third is the percentage change in the bid-ask spread from one day to the next.

The first two panels in Figure 3.14 report the average and standard deviation of the percentage drop in trading volume compared to the previous trading day of those option contracts experiencing a drop (i.e., how big drops in volume are if they happen). Conditional on occurring, drops in volume are actually smaller for front-month options than for back-month options, and they tend to become less severe as one gets closer to expiration. Thus, the risk of not being able to exit a position in a particular option contract due to volume drying up is lower for front-month options than for back-month options. The standard deviation of volume drops is slightly larger for front-month options than for back-month options until seven days before the expiration of the front month, but falls sharply – and is lower than for back-month options – during the last two days before expiration.

The next two panels in Figure 3.14 report the average and standard deviation of the ratio of option volume to open interest on the previous day – the options market equivalent of turnover. Here, a lower average and a higher standard deviation would indicate a greater risk of not being able to close a position. The results reveal that the average and standard deviation of turnover are particularly large for back-month options between 20 and 18 days before the expiration of the front month. Apart from that, both mean and standard deviation are very similar for front-month and back-month options. For front-month options, there is even an increase in average turnover during the two days before expiration, reflecting the increase in volume and decrease in open interest reported in Figure 3.13. Thus, based on this measure as well, there is no evidence that liquidity risk is larger for front-month options close to expiration than at other times, nor that it is higher for front-month options than for back-month options.

The last two panels in Figure 3.14 show the cross-sectional average and standard deviation of percentage changes in the relative bid-ask spread from one day to the next. Both the average and standard deviation of changes in spreads are higher for front-month options than for back-month options, and rise sharply as front-month options approach maturity. Thus, sellers of front-month options face increasing risk of having to bear large transaction costs to exit positions as maturity approaches. Together with the difficulty of delta-hedging these options, this liquidity risk explains why the put option premium is concentrated shortly before maturity.

3.4.6 Robustness and Extensions

Before concluding, we briefly review a number of robustness checks that we have performed and provide a short overview of our findings for other categories of options. As mentioned in Section 3.3, our results are robust to several variations in our methodology, in particular (i) screening calls and puts together rather than separately, (ii) screening options using open interest rather than volume or using same-day volume rather than lagged volume, (iii) varying the percentage of options that are retained in the liquidity screening, (iv) delta-hedging options using a model-free approximation of delta rather than the values provided by OptionMetrics.

We also investigated selecting the set of OTM put options to short based on the level of market volatility measured using the VIX index. This revised approach involves shorting options that are deeper OTM when market volatility is high. The returns achieved when doing so are even more attractive than those presented above, and our finding that the OTM put option premium mainly accrues shortly before expiration is robust to this change.

While our discussion has focused on OTM put options, we have also considered OTM call options, as well as ATM and ITM options of both types. The returns on OTM call options exhibit patterns similar to OTM puts, but the premium earned by shorting calls is lower than for puts and the return distributions are wider. Since OTM calls also have lower trading volume than OTM puts (see Figure 3.2), they appear less attractive to implement the strategies described in this paper. ATM options, both calls and puts, exhibit return patterns similar to those reported for OTM options, but earn a lower premium overall and exhibit more frequent drawdowns because of their higher likelihood of finishing in the money. ITM options barely earn any premium and do not exhibit end-of-cycle return patterns.

We have also investigated the presence of end-of-cycle return patterns for options on other underlying assets. End-of-cycle patterns similar to those presented above for SPX options can be found in NASDAQ-100 index options (the sample period considered in this analysis, 1996-2015, is the same as that for SPX options). Pronounced end-of-cycle return patterns are also present for VIX options during the period 2007-2016, especially starting from the Friday preceding the expiration Wednesday of VIX derivative products.[33,34]

3.5 Conclusion

This paper documents empirically that the returns from shorting out-of-the-money S&P 500 put options are concentrated in the few days preceding their expiration. Back-month options generate almost no returns, and front-month options do so only towards the end of the option cycle. Strikingly, we find that shorting front-month OTM put options during the last week or even the last day of the option cycle earns returns that are as high as or even higher than those earned by shorting OTM put options during the entire cycle, both on a raw and on a risk-adjusted basis.

We investigate a number of potential explanations for the large returns that we document. The returns are specific to the front-month contract and specific to the few days before expiration, making it appear unlikely that they are driven by market frictions. Rather, the concentration of the option premium at the end of the cycle reflects changes in options' risk characteristics during the cycle. Specifically, options' convexity risk increases sharply close to maturity, making them more sensitive to jumps in the underlying price. By contrast, volatility risk plays a smaller role close to maturity.

The key implications of our findings are that portfolio managers wishing to harvest the OTM option premium should short front-month options and do so only over the last days of the cycle, while investors wishing to protect their equity portfolios against downside risk should use back-month options to reduce hedging costs.

Most of the literature on the empirical performance of option pricing models has typically not

[33]VIX options were introduced late February 2006 but volume was initially low, with about 5 million contracts traded in 2006. In 2007, volume was about 23 million contracts.

[34]Although we have not performed a complete analysis of the return patterns for single stock options, we find that for the S&P 500 constituents and during the period 1996-2015, the volatility risk premium (measured as implied volatility minus realized volatility during the life of the contract) is much larger during the last week of the option cycle than during other weeks. Moreover, the risk premium of OTM options is statistically different from zero during the last week but not in other weeks, confirming that the pricing of options at the end of the cycle differs from that during other weeks. We leave a detailed investigation of single stock options to future research.

considered very short-term options due to illiquidity concerns. Yet, our results show that options are actually quite liquid towards the end of the cycle, and most of their returns accrue during that time. An interesting avenue for future research would be to investigate the performance of these models during the few days preceding expiration. It would also be interesting to investigate whether the effects that we document are also present in options on other classes of assets.

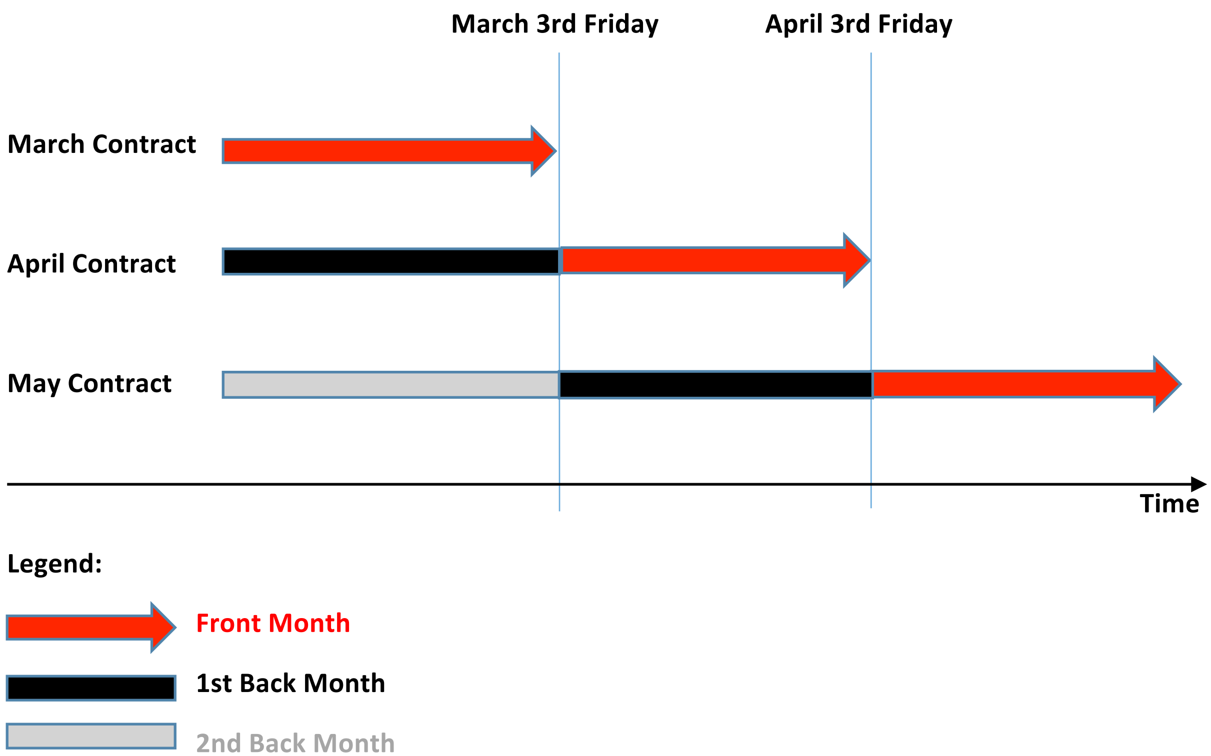

Figure 3.1
Illustration of Front-Month and Back-Month Options

This figure illustrates the concept of front-month and back-month options. At the beginning of March, the front-month contract is the one maturing on the third Friday of March, and the (first) back-month contract that maturing on the third Friday of April. At the end of March, the front-month contract is April, and the back-month contract is May. After the April expiration, the May contract is the new front-month contract.

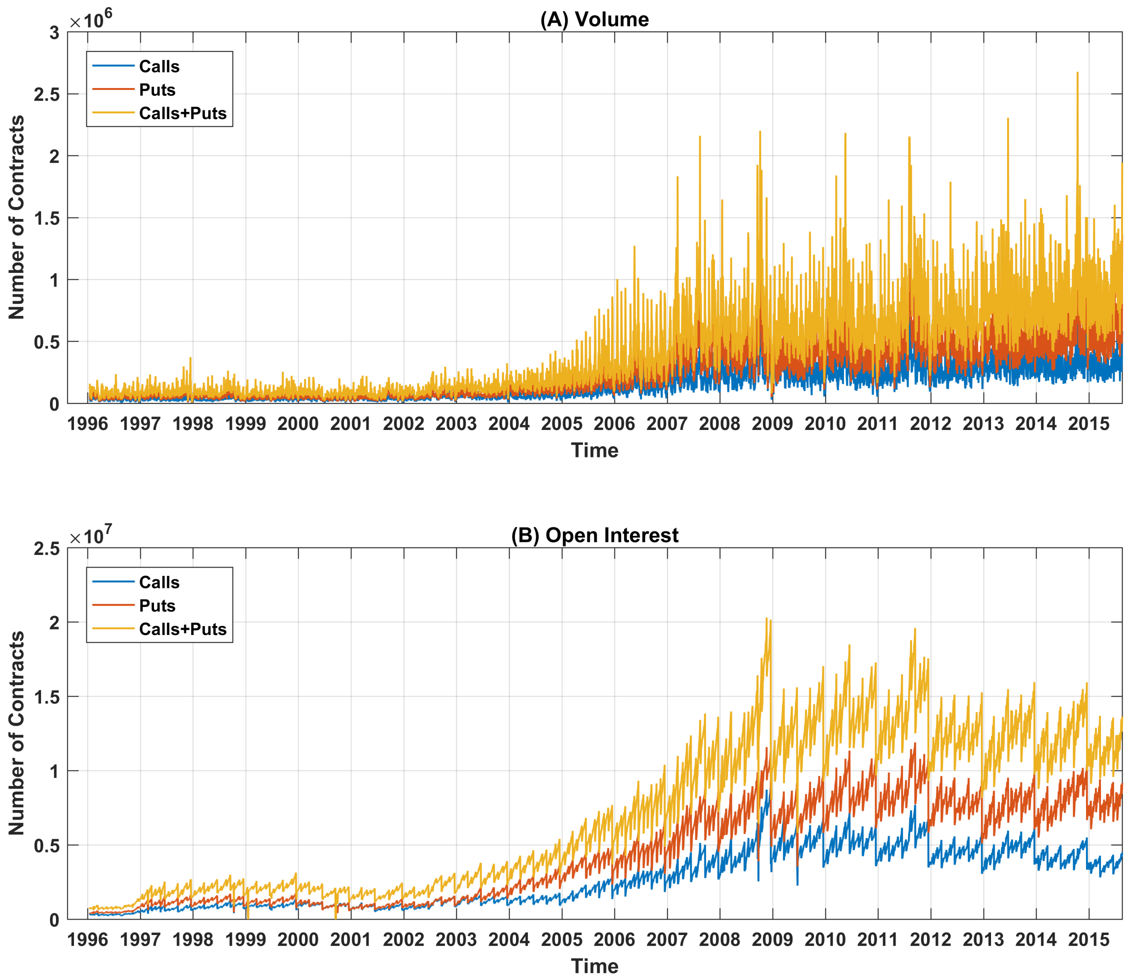

Figure 3.2
Volume and Open Interest for S&P 500 Index Options

This figure reports monthly aggregate trading volume (Panel A) and open interest (Panel B) of S&P 500 index options for call options, put options, and all options. The data are aggregated over all strikes and maturities. The sample period is January 1996 to August 2015.

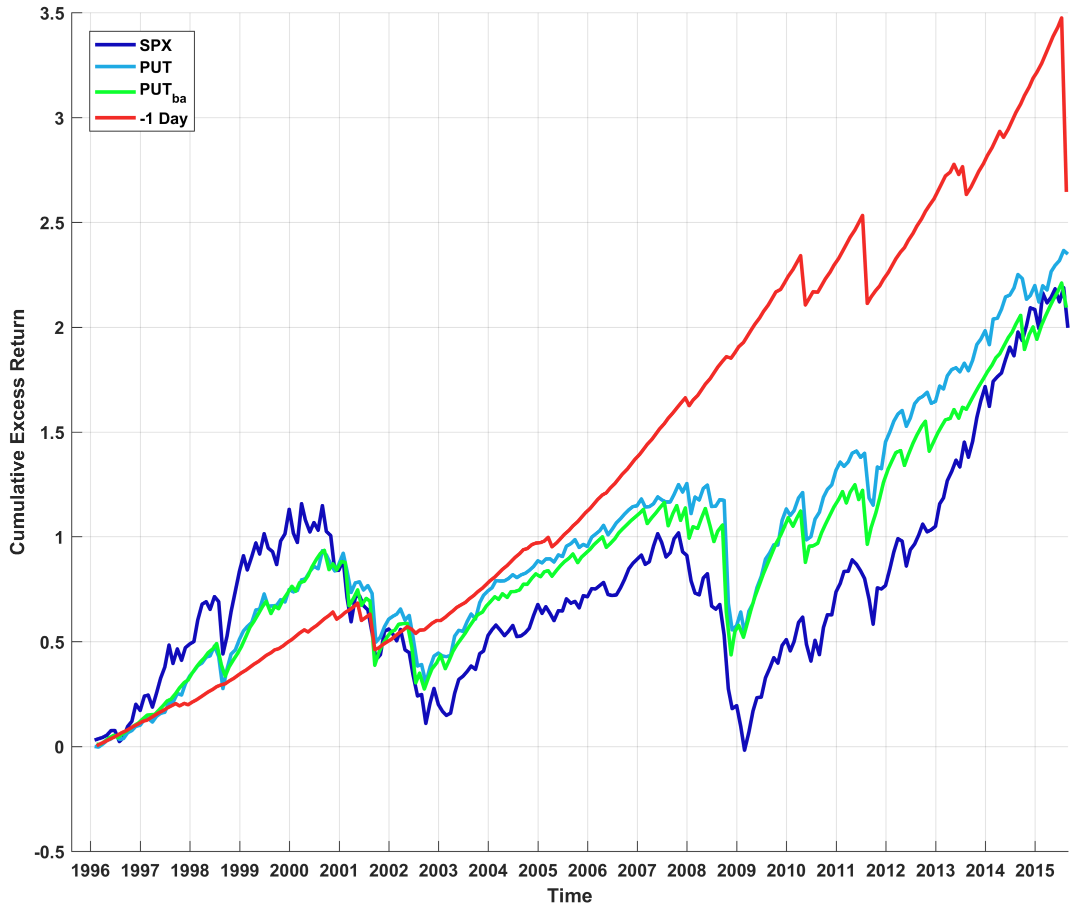

Figure 3.3
Cumulative Excess Returns on the Underlying Index and Option Strategies

This figure shows the cumulative excess returns of the S&P 500 total return index (denoted SPX), the CBOE Put index (denoted PUT), our implementation of the Put index trading at the close of each trading day and accounting for transaction costs (denoted PUT_{ba}), as well as the cumulative excess returns achieved by shorting OTM put option portfolios for the last day of the monthly option cycle and holding the position to maturity, also accounting for transaction costs (denoted -1 Day). The option positions are entered at the bid price prevailing at the close of the market on the penultimate day of the option cycle and their final settlement price is computed using the S&P 500 special opening quotation on the expiration date. The sample period is January 1996 to August 2015.

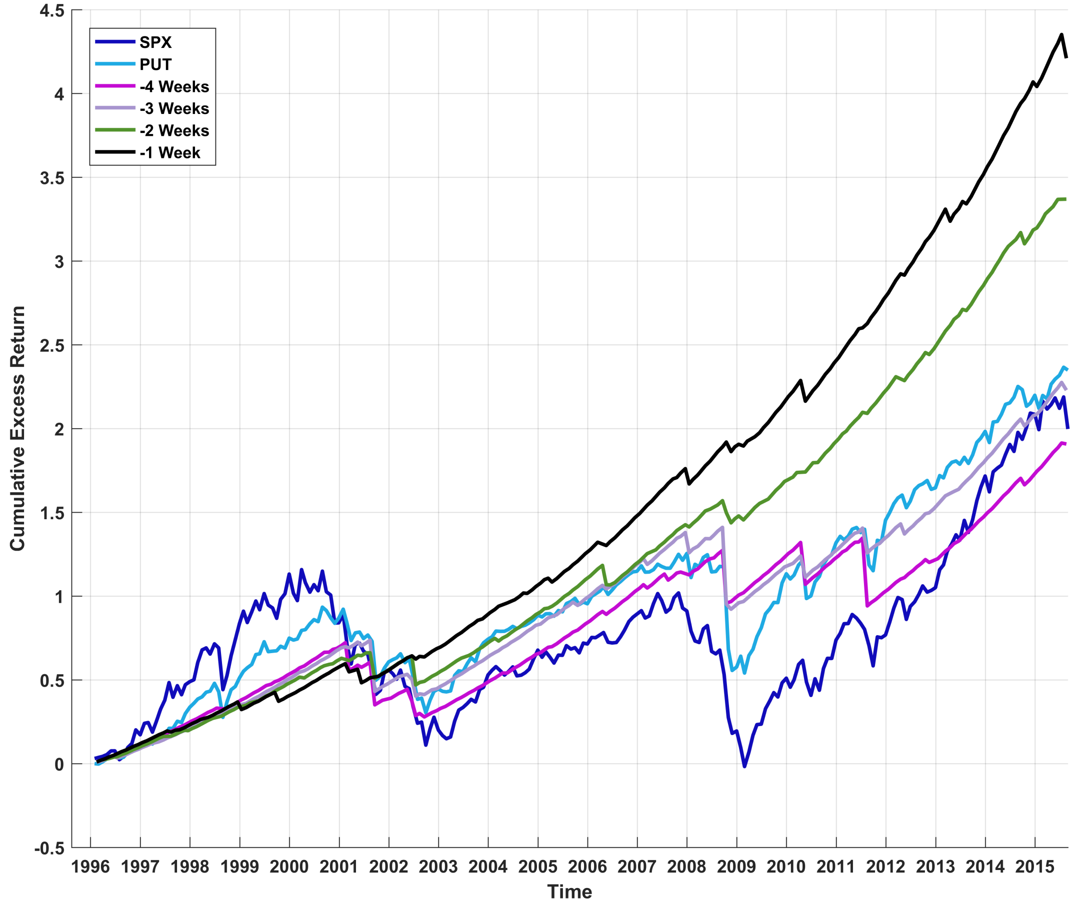

Figure 3.4
Cumulative Excess Returns on the Underlying Index and Option Strategies

This figure shows the cumulative excess returns of the S&P 500 total return index (denoted SPX), the CBOE Put index (denoted PUT), as well as the cumulative excess returns achieved by shorting portfolios of front-month OTM put options 4, 3, 2, and 1 weeks before expiration and holding them to maturity. In each case, the positions are entered at the bid price prevailing at the close of the market on Friday and the options' final settlement price is computed using the S&P 500 special opening quotation on the expiration date. The sample period is January 1996 to August 2015.

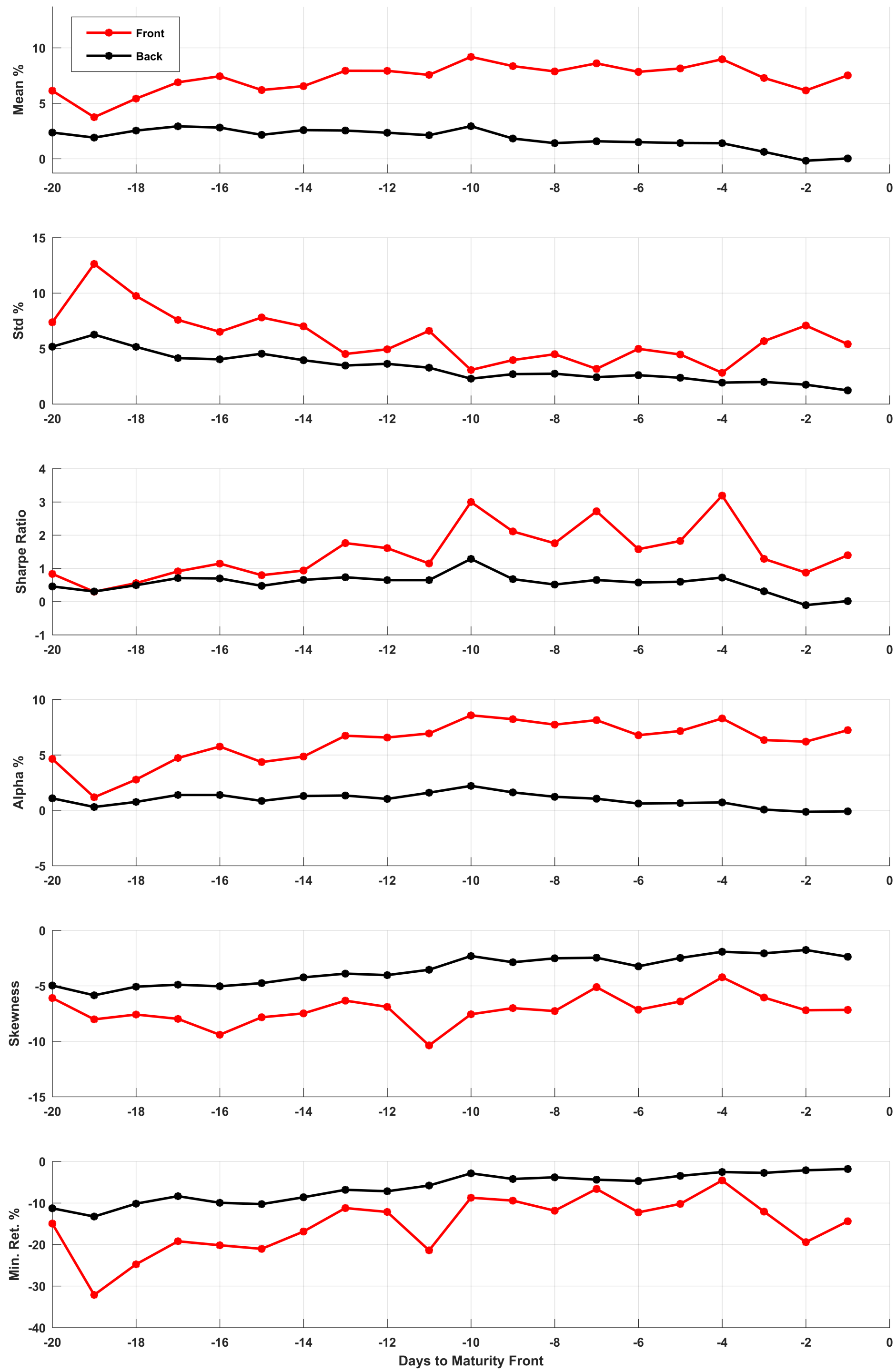

Figure 3.5
Excess Returns from Selling OTM Put Options at Different Points in the Cycle

This figure summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at mid-prices. Front-month options are held until maturity, while positions in back-month options are covered at the close of the market on the day preceding the expiration of the front month. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. The sample period is January 1996 to August 2015.

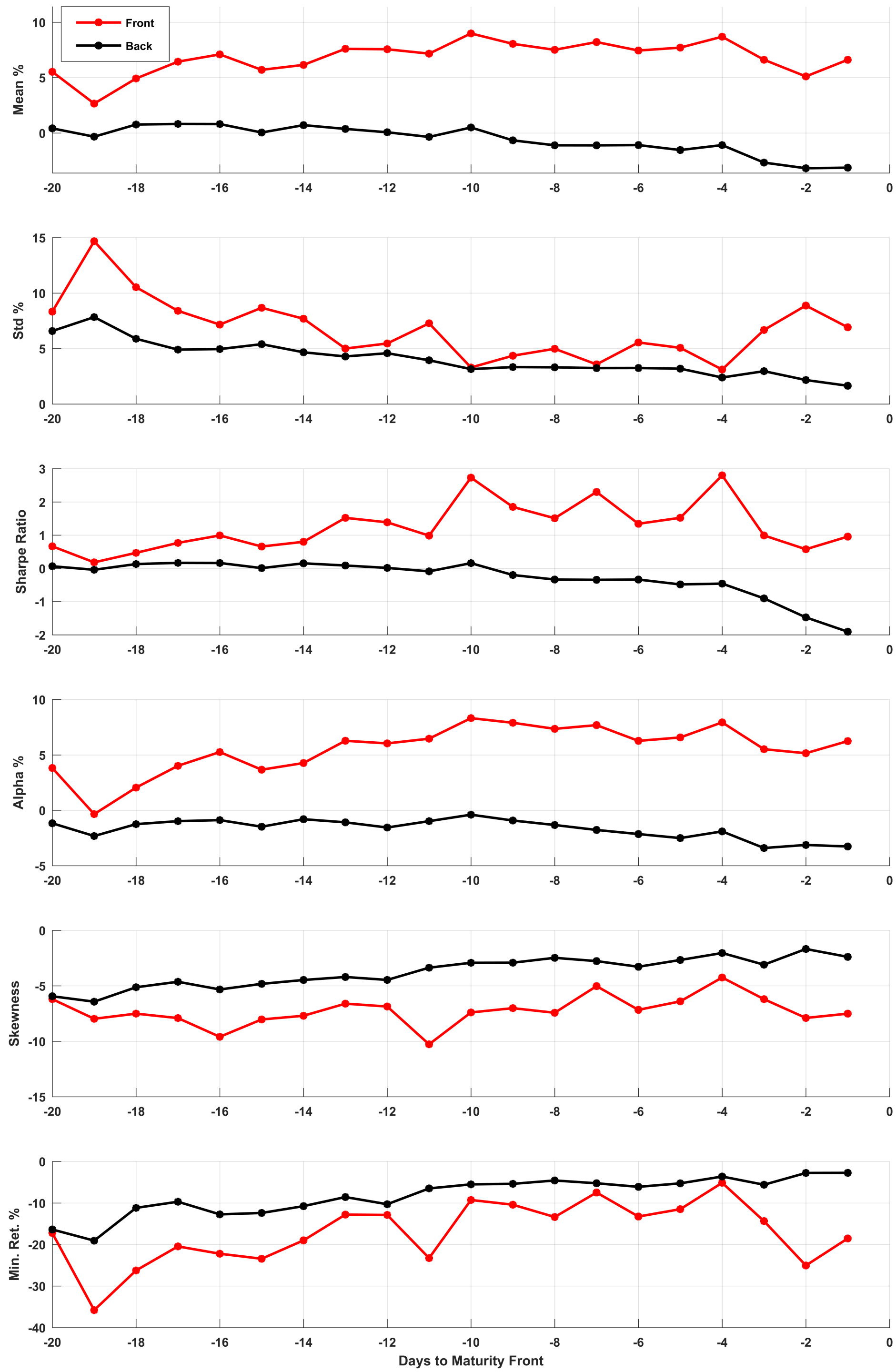

Figure 3.6
Excess Returns from Selling OTM Put Options at Different Points in the Cycle with Transaction Costs

This figure summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transactions are conducted at bid or ask prices. Front-month options are held until maturity, while positions in back-month options are covered at the close of the market on the day preceding the expiration of the front month. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. The sample period is January 1996 to August 2015.

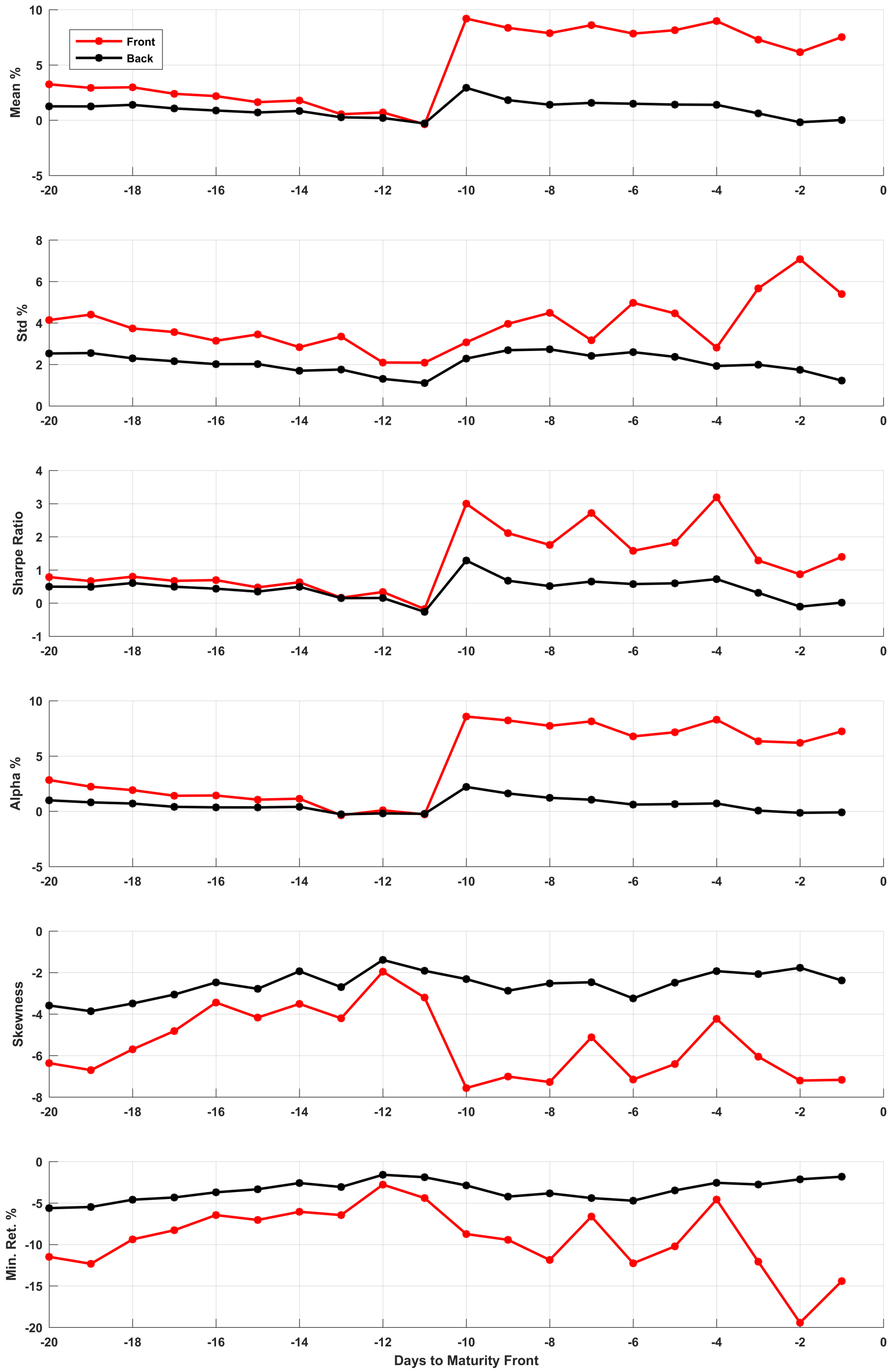

Figure 3.7
Excess Returns from Selling OTM Put Options at the Beginning and at the End of the Cycle

This figure summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at mid-prices. Positions opened between 20 and 11 trading days before maturity are closed ten days before maturity, while positions opened between ten days and one day before maturity are held until maturity for front-month options and closed on the evening preceding the expiration of the front month for back-month options. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. The sample period is January 1996 to August 2015.

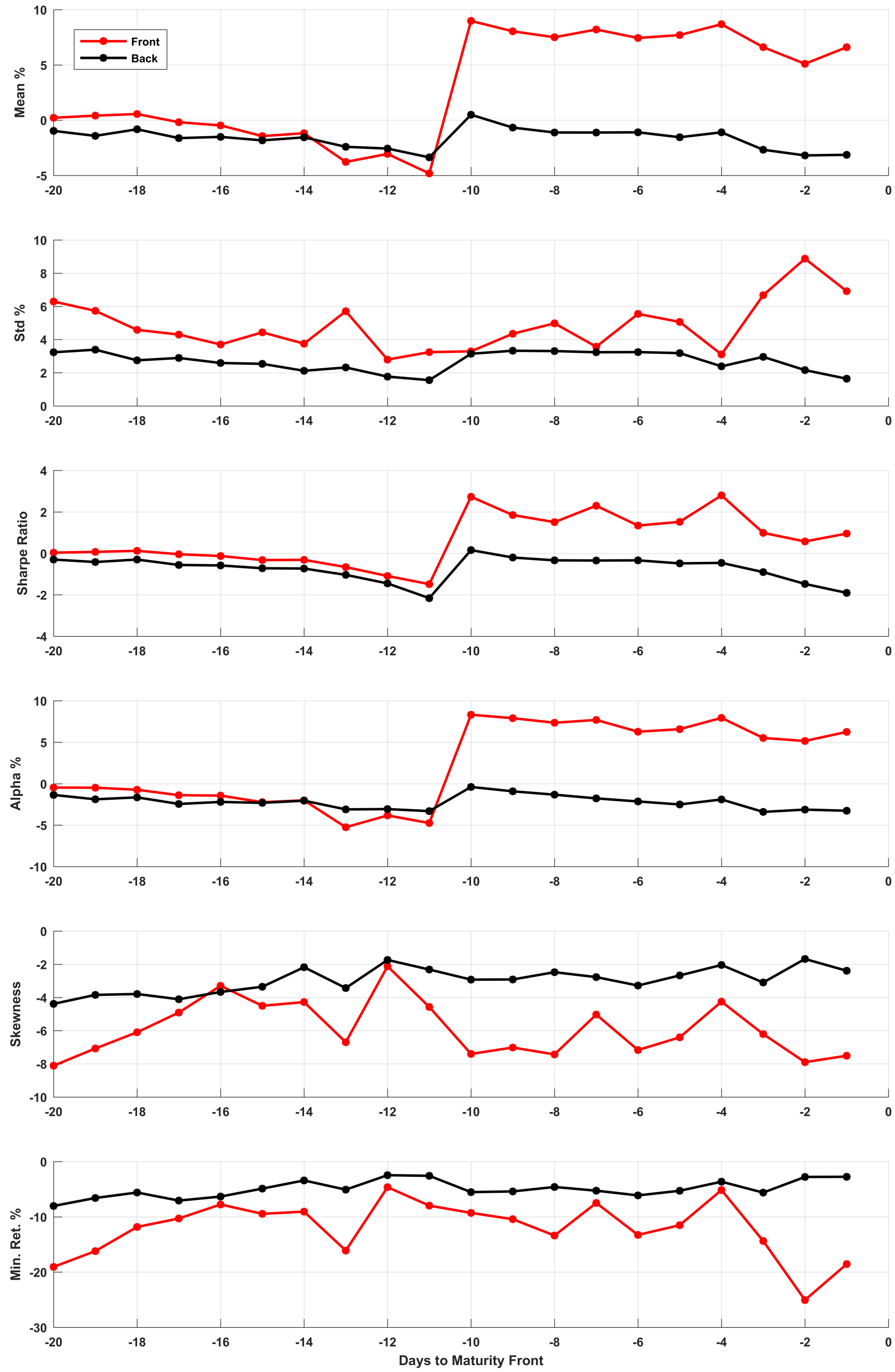

Figure 3.8
Excess Returns from Selling OTM Put Options at the Beginning and at the End of the Cycle with Transaction Costs

This figure summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at bid or ask prices. Positions opened between 20 and 11 trading days before maturity are closed ten days before maturity, while positions opened between ten days and one day before maturity are held until maturity for front-month options and closed on the evening preceding the expiration of the front month for back-month options. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. The sample period is January 1996 to August 2015.

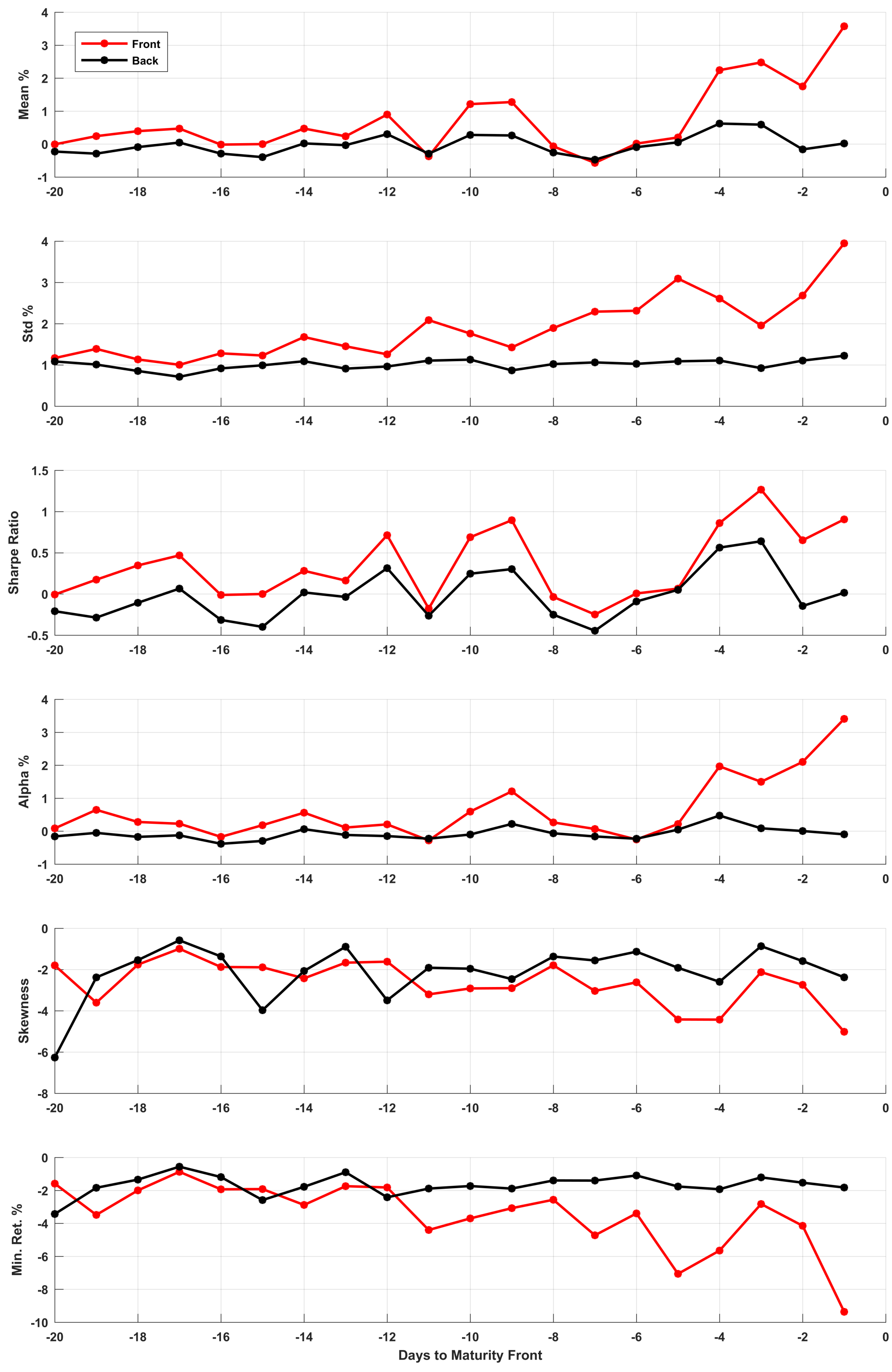

Figure 3.9
Excess Returns from Selling OTM Put Options for a Single Day

This figure summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All positions are held for a single trading day, and all transaction are conducted at mid-prices. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, skewness, and the worst return during the sample period. The sample period is January 1996 to August 2015.

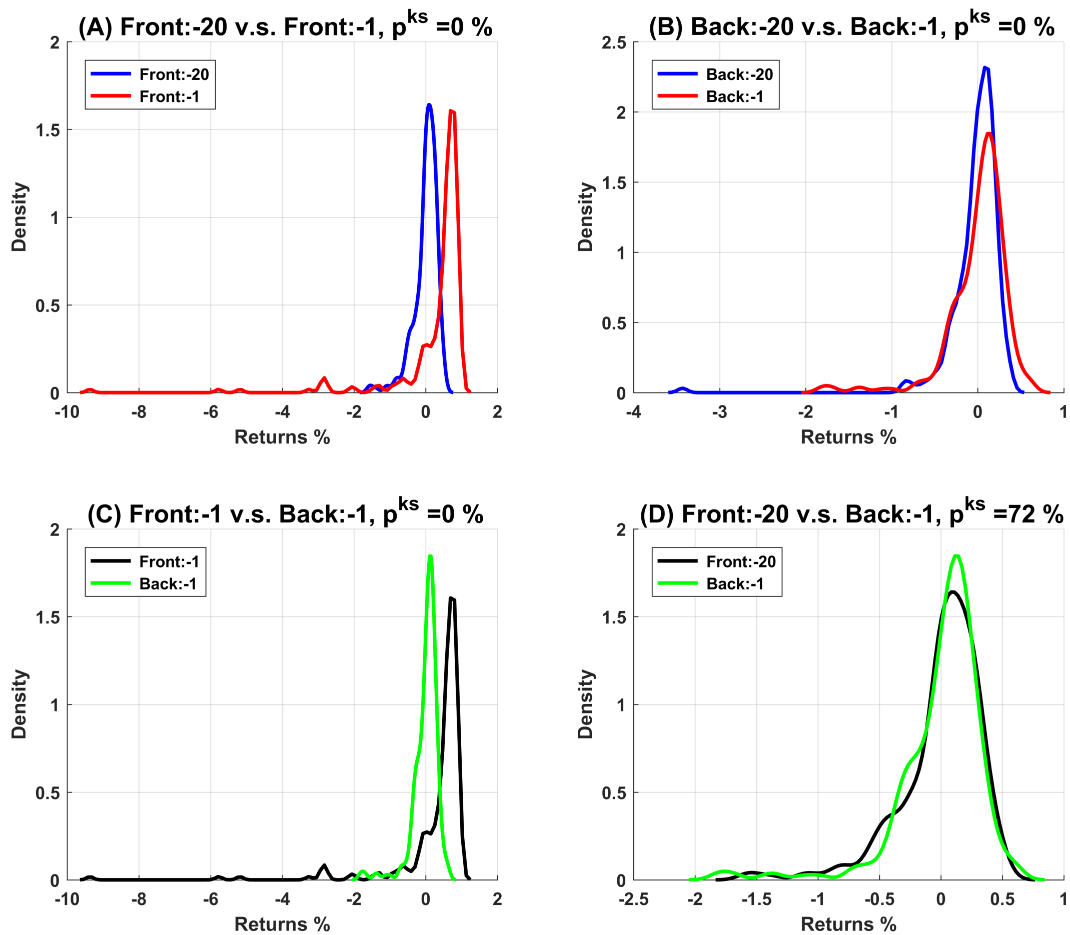

Figure 3.10

Kernel Density Estimates of the Excess Returns of OTM Put Option Portfolios

This figure shows non-parametric kernel density estimates of the excess returns of OTM put option portfolios for the front and back month at different points during the option cycle. Each panel reports two distributions as well as the p-values of non-parametric two-sample Kolmogorov-Smirnov tests that they are identical. Panel A contrasts the return distribution of the front month 20 days to maturity with that one day before maturity. Panel B performs a similar comparison for the back month. Panel C compares the return distributions of both contracts on the day preceding the expiration of the front month. Panel D contrasts the return distributions of the back month one day before the expiration of the front month with those of the front month 20 days before expiration; in a typical month, this corresponds to the first day that the contract is the front month. All transactions are conducted at mid-prices. The sample period is January 1996 to August 2015.

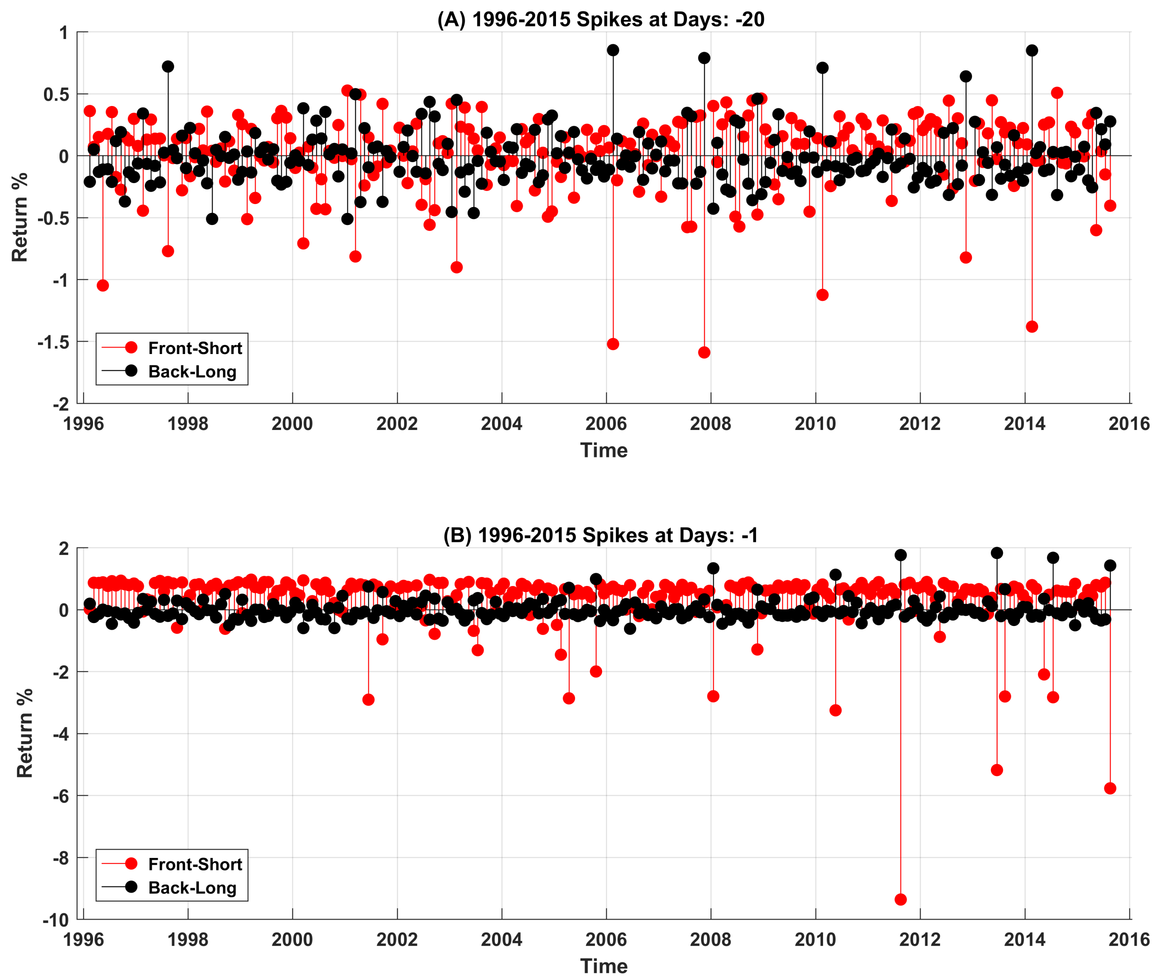

Figure 3.11
Time-Series of Daily Excess Returns of OTM Put Option Portfolios

This figure shows the time-series of the one-day returns of portfolios of front-month and back-month OTM put options at different points in the monthly option cycle. Panel A reports the returns 20 days before the expiration of the front month, while Panel B shows those one day before maturity. To improve readability, the returns are reported as if front-month options were held short and back-month options were held long. All transactions are conducted at mid-prices. The sample period is January 1996 to August 2015.

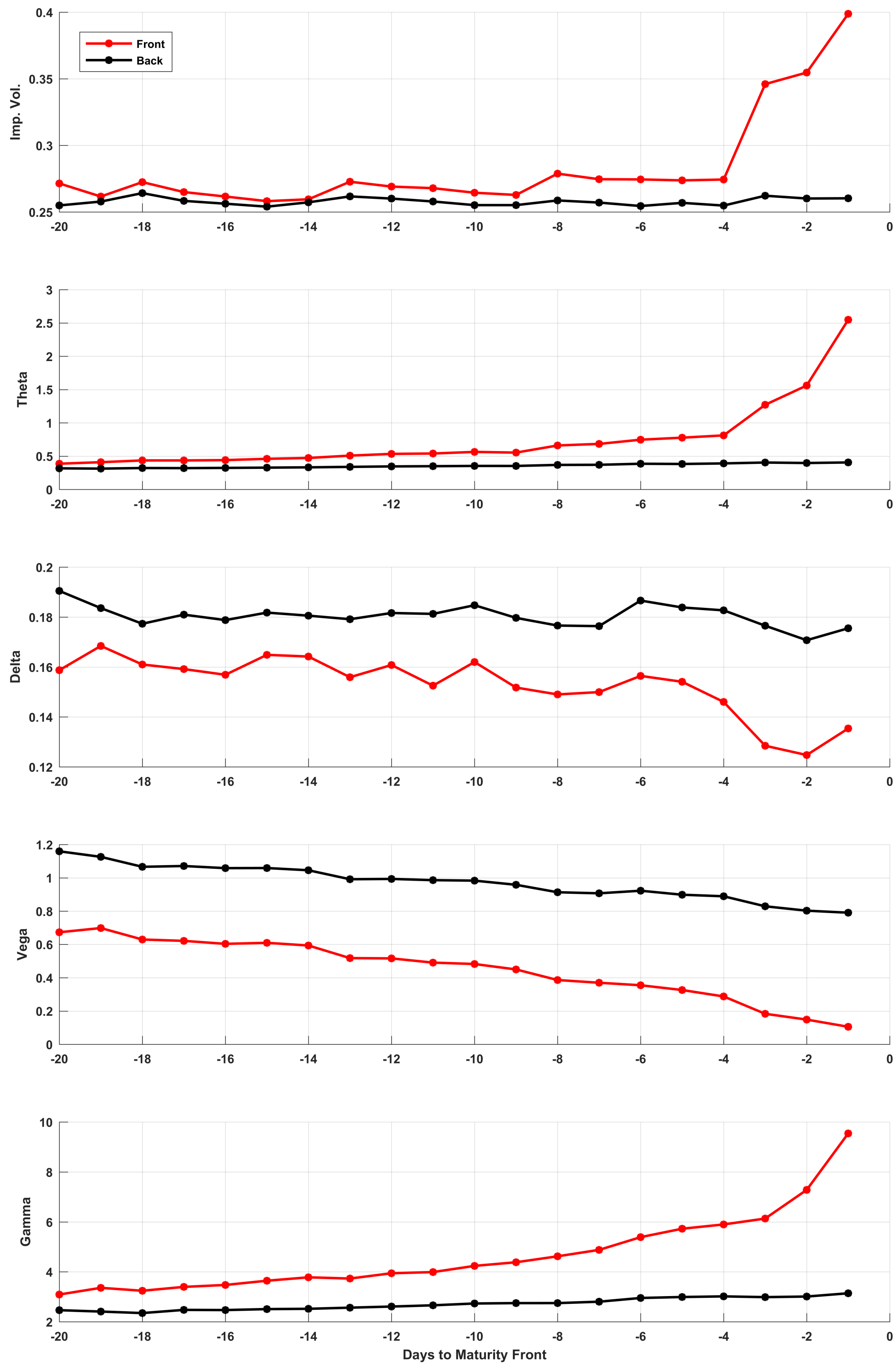

Figure 3.12
Average Implied Volatility and Greeks of OTM Put Option Portfolios

This figure reports the average implied volatility and Greeks of the option portfolios at different points during the option cycle, measured as the number of business days until the expiration of the front-month contract. Implied volatility is annualized, and all Greeks are reported in absolute value. Gamma is multiplied by one thousand to improve readability, theta is reported in dollars per day, and vega represents the dollar change in the option price for a one percentage change in implied volatility. The sample period is January 1996 to August 2015.

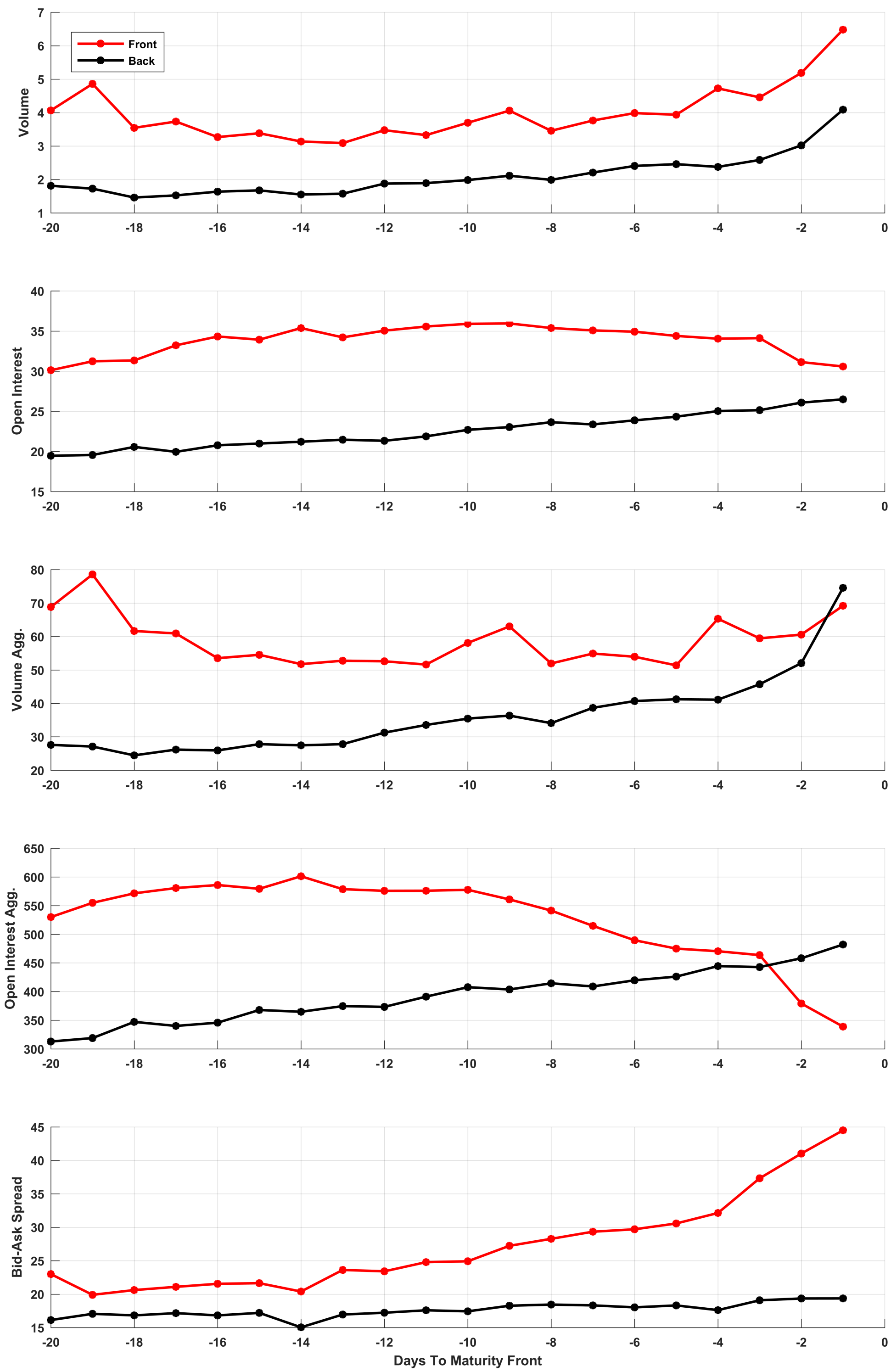

Figure 3.13
Liquidity Measures of OTM Put Option Portfolios

This figure reports a number of liquidity measures of the option portfolios at different points during the option cycle, measured as the number of business days until the expiration of the front-month contract. The top two panels report the average daily volume and open interest of the strikes included in the portfolios in thousands of contracts. The next two panels report the aggregate volume and open interest of all strikes included in the portfolios, again in thousands of contracts. The last panel reports the percentage bid-ask spread relative to the mid-price. The sample period is January 1996 to August 2015.

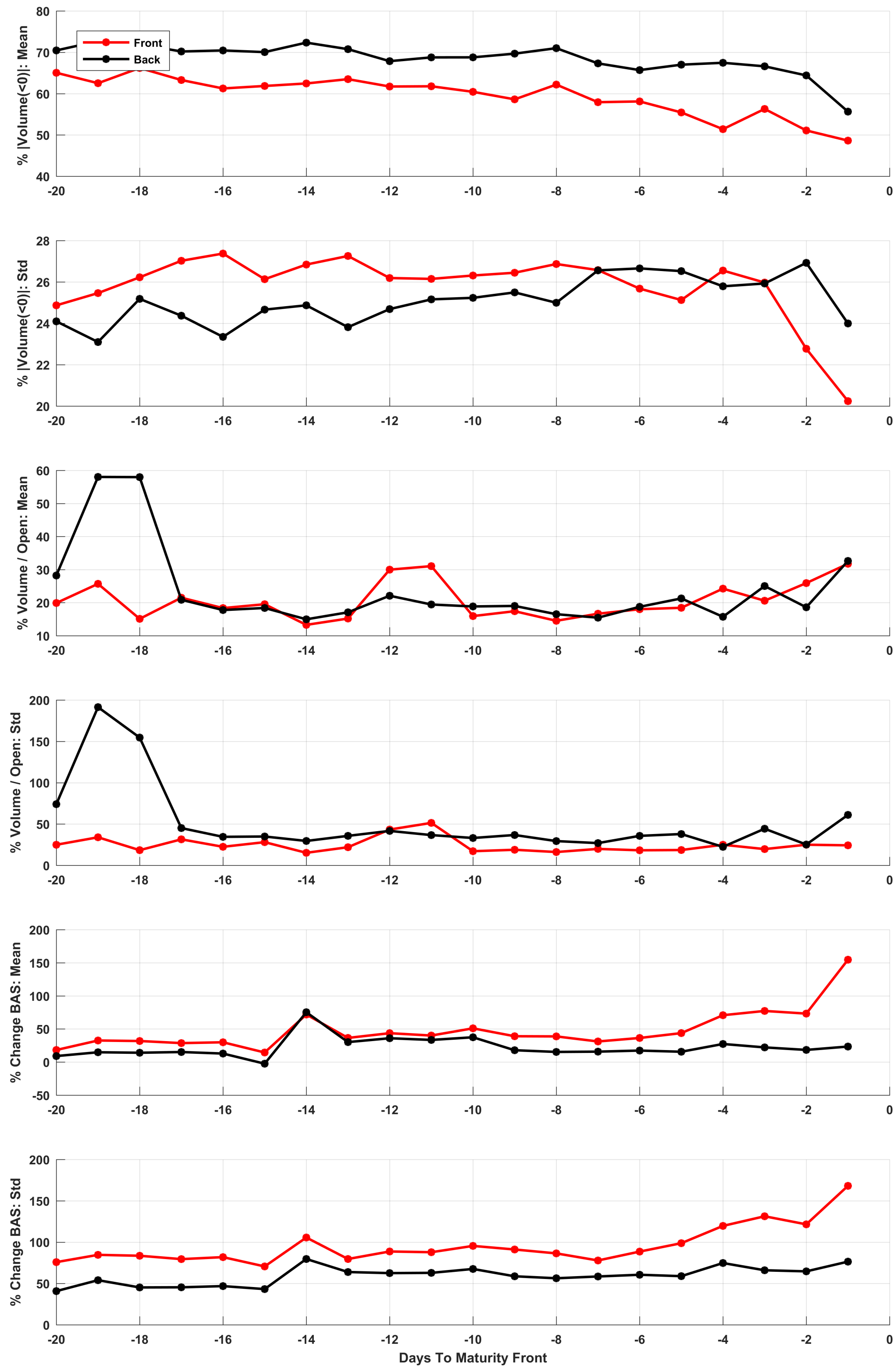

Figure 3.14
Liquidity Risk of OTM Put Option Portfolios

This figure shows a number of liquidity risk measures of option portfolios at different points during the option cycle, measured as the number of business days until the expiration of the front-month contract. The top two panels report the cross-sectional average (Mean) and standard deviation (Std) of the percentage drop in trading volume compared to the previous trading day for those option contracts experiencing a drop. The next two panels report the cross-sectional average and standard deviation of the ratio of trading volume to open interest in percentage points. The last two panels report the cross-sectional average and standard deviation of percentage changes in the bid-ask spread from one day to the next. The sample period is January 1996 to August 2015.

Table 3.1
Performance of Benchmark Indices and Option Strategies

This table presents performance statistics for the benchmark indices and a number of option writing strategies. The table reports average excess returns, their standard deviation, Sharpe ratio (SR), skewness, kurtosis, worst and best return, the alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, and first-order return autocorrelation ρ. Average returns, standard deviations, and alphas are in percent per year, and Sharpe ratios are annualized. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). Panel A considers the S&P 500 total return index (denoted SPX), the CBOE Put index (denoted PUT), and our implementation of the Put index trading at the close of each trading day and accounting for transaction costs (denoted PUT_{ba}). Panel B describes the unhedged returns achieved by shorting portfolios of front-month OTM put options 4, 3, 2, and 1 weeks as well as one day before maturity and holding them to maturity. Panel C presents the unhedged returns from shorting similar options four weeks before maturity and closing the position a certain number of weeks before maturity. Panels D and E present the returns of strategies with the same entry and exit times as those in Panels B and C but with delta-hedging. All option transactions are conducted at bid or ask prices. The final settlement price of options held to maturity is computed using the S&P 500 special opening quotation on the expiration date. The sample period is January 1996 to August 2015.

(A) Benchmarks	Mean	Std	SR	Skw	Kur	Min	Max	α	t-α	ρ
SPX	5.58	15.47	0.36	-0.81	4.41	-16.78	10.90	0.33	1.38	0.08
PUT	6.14	11.53	0.53	-3.06	20.97	-22.60	8.45	2.85	1.79	0.08
PUT_{ba}	5.77	12.14	0.47	-3.31	17.42	-20.15	7.77	2.27	1.71	0.03
(B) Unhedged Returns, Hold to Maturity										
-4 Weeks	5.52	8.33	0.66	-6.20	43.19	-17.25	1.00	3.82	2.21	-0.01
-3 Weeks	6.14	7.69	0.80	-7.70	69.24	-19.01	1.00	4.27	3.10	0.03
-2 Weeks	8.04	4.35	1.85	-7.01	58.75	-10.43	1.00	7.90	9.08	0.05
-1 Week	8.69	3.11	2.80	-4.25	21.90	-5.16	1.00	7.93	10.48	-0.06
-1 Day	6.60	6.92	0.95	-7.51	67.56	-18.55	1.00	6.24	4.24	-0.02
(C) Unhedged Returns, Close Positions Before Maturity										
-4 to -3 Weeks	-1.66	3.77	-0.44	-3.88	22.74	-7.92	0.82	-1.78	-2.44	-0.06
-4 to -2 Weeks	0.62	7.57	0.08	-7.28	63.86	-19.79	0.94	-0.87	-0.49	-0.06
-4 to -1 Weeks	2.27	9.38	0.24	-9.46	107.61	-28.22	0.98	0.81	0.41	-0.01
(D) Δ-Hedged Returns, Hold to Maturity										
-4 Weeks	4.11	6.53	0.63	-3.75	24.20	-11.75	5.00	3.75	2.28	-0.06
-3 Weeks	3.05	6.48	0.47	-5.31	45.29	-14.91	3.12	2.99	1.85	-0.11
-2 Weeks	6.81	4.73	1.44	-1.54	10.08	-6.85	3.49	7.18	7.65	-0.08
-1 Week	5.22	4.14	1.26	-0.14	2.78	-2.91	3.20	6.47	8.01	0.01
-1 Day	5.00	6.62	0.76	-3.35	23.49	-13.81	5.47	5.31	3.57	-0.01
(E) Δ-Hedged Returns, Close Positions Before Maturity										
-4 to -3 Weeks	-0.85	2.37	-0.36	-4.57	31.85	-5.57	0.96	-1.24	-2.06	-0.01
-4 to -2 Weeks	-0.04	5.69	-0.01	-7.63	69.61	-15.52	1.15	-0.79	-0.50	-0.02
-4 to -1 Weeks	2.07	7.35	0.28	-9.53	114.94	-23.39	1.94	1.10	0.56	-0.02

Table 3.2
Distribution of Excess Returns from Selling OTM Put Options at Different Points in the Cycle

This table summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at mid-prices. Front-month options are held until maturity, while positions in back-month options are covered at the close of the market on the day preceding the expiration of the front month. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, skewness, and the worst return during the sample period. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The sample period is January 1996 to August 2015.

	Front							Front Delta-Hedged							Back							Back Delta-Hedged						
Day	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min
-20	6.14	7.36	0.83	4.63	3.02	-6.10	-14.96	4.68	5.76	0.81	4.27	2.98	-4.27	-10.77	2.36	5.17	0.46	1.08	1.22	-4.97	-11.29	1.39	3.48	0.40	0.85	1.03	-5.49	-8.40
-19	3.75	12.63	0.30	1.17	0.42	-8.03	-32.14	2.16	10.25	0.21	0.89	0.34	-7.60	-27.08	1.90	6.26	0.30	0.30	0.29	-5.86	-13.27	0.79	4.48	0.18	0.02	0.02	-6.26	-10.52
-18	5.42	9.74	0.56	2.77	1.13	-7.59	-24.77	3.35	7.75	0.43	2.50	1.10	-6.49	-19.87	2.54	5.15	0.49	0.75	0.75	-5.08	-10.18	1.11	3.48	0.32	0.48	0.52	-5.05	-7.02
-17	6.89	7.58	0.91	4.72	2.58	-7.98	-19.22	4.38	6.33	0.69	3.94	2.22	-5.64	-14.98	2.92	4.14	0.71	1.39	1.88	-4.90	-8.37	1.36	2.67	0.51	0.92	1.32	-5.03	-5.62
-16	7.44	6.51	1.14	5.75	3.12	-9.41	-20.18	5.00	5.55	0.90	5.05	3.03	-6.52	-16.14	2.81	4.03	0.70	1.39	1.70	-5.04	-9.96	1.32	2.56	0.52	0.99	1.42	-5.85	-7.23
-15	6.20	7.80	0.79	4.35	3.11	-7.84	-21.05	3.90	6.49	0.60	3.43	2.17	-5.98	-17.09	2.15	4.53	0.47	0.84	1.35	-4.76	-10.29	0.78	2.93	0.27	0.33	0.46	-5.69	-7.67
-14	6.55	7.00	0.94	4.85	3.82	-7.49	-16.88	3.74	5.80	0.64	3.64	2.54	-5.41	-13.25	2.58	3.95	0.65	1.29	2.60	-4.24	-8.64	0.93	2.42	0.38	0.61	1.05	-4.91	-6.20
-13	7.94	4.51	1.76	6.73	6.60	-6.34	-11.23	5.38	4.11	1.31	5.96	5.66	-2.20	-7.79	2.54	3.47	0.73	1.33	2.20	-3.90	-6.83	1.08	2.10	0.52	0.94	1.79	-4.73	-4.85
-12	7.93	4.93	1.61	6.57	6.97	-6.90	-12.17	5.03	4.34	1.16	5.41	4.67	-2.85	-8.68	2.34	3.62	0.65	1.03	2.09	-4.04	-7.19	0.76	2.24	0.34	0.46	0.75	-4.37	-5.15
-11	7.56	6.60	1.15	6.93	5.05	-10.38	-21.41	5.72	5.75	0.99	5.91	4.36	-7.54	-17.50	2.12	3.27	0.65	1.59	4.09	-3.55	-5.81	1.14	1.92	0.59	1.07	2.59	-3.62	-3.54
-10	9.19	3.07	3.00	8.57	13.52	-7.57	-8.74	6.75	3.55	1.90	7.57	9.47	-1.37	-6.09	2.93	2.28	1.28	2.21	8.21	-2.31	-2.88	1.68	1.21	1.38	1.75	6.27	-1.55	-1.33
-9	8.35	3.96	2.11	8.22	10.35	-7.01	-9.44	7.16	3.94	1.82	7.43	8.93	-1.97	-6.20	1.82	2.69	0.68	1.61	4.50	-2.88	-4.23	1.28	1.41	0.91	1.28	3.81	-2.76	-2.21
-8	7.87	4.49	1.75	7.73	8.30	-7.28	-11.87	6.65	4.22	1.57	6.94	7.72	-2.76	-8.65	1.40	2.73	0.51	1.22	3.23	-2.52	-3.83	0.86	1.41	0.61	0.89	2.62	-2.50	-2.09
-7	8.60	3.17	2.72	8.14	10.59	-5.12	-6.63	6.75	3.56	1.89	7.40	9.41	-0.18	-2.59	1.57	2.41	0.65	1.05	3.00	-2.47	-4.40	0.78	1.18	0.66	0.78	2.65	-2.71	-2.38
-6	7.84	4.97	1.58	6.78	4.95	-7.15	-12.27	5.19	4.45	1.17	5.96	4.68	-2.37	-7.80	1.49	2.60	0.57	0.61	1.45	-3.25	-4.72	0.37	1.35	0.28	0.29	0.84	-3.88	-2.67
-5	8.14	4.46	1.83	7.15	5.72	-6.41	-10.23	5.47	4.13	1.32	6.08	4.86	-1.72	-6.70	1.41	2.37	0.60	0.65	2.02	-2.49	-3.48	0.30	1.13	0.27	0.20	0.72	-2.98	-2.26
-4	8.97	2.81	3.19	8.29	11.98	-4.23	-4.58	6.33	3.29	1.93	7.24	10.40	0.01	-1.83	1.39	1.93	0.72	0.71	2.76	-1.93	-2.56	0.33	0.86	0.38	0.25	1.27	-2.00	-1.39
-3	7.28	5.67	1.29	6.34	4.40	-6.05	-12.08	5.15	4.97	1.04	5.52	4.27	-1.98	-7.81	0.62	1.99	0.31	0.07	0.24	-2.07	-2.77	-0.20	0.94	-0.22	-0.31	-1.42	-2.57	-1.56
-2	6.16	7.07	0.87	6.20	4.27	-7.21	-19.44	5.99	5.93	1.01	5.88	4.62	-4.58	-14.84	-0.18	1.74	-0.11	-0.14	-0.61	-1.77	-2.14	-0.26	0.80	-0.32	-0.26	-1.52	-2.15	-1.01
-1	7.52	5.39	1.39	7.23	6.37	-7.17	-14.42	6.49	4.87	1.33	6.68	5.94	-3.73	-10.71	0.02	1.22	0.02	-0.10	-0.63	-2.38	-1.83	-0.16	0.62	-0.26	-0.17	-1.33	-4.11	-1.20

Table 3.3
Distribution of Excess Returns from Selling OTM Put Options at Different Points in the Cycle with Transaction Costs

This table summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at bid or ask prices. Front-month options are held until maturity, while positions in back-month options are covered at the close of the market on the day preceding the expiration of the front month. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, skewness, and the worst return during the sample period. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The sample period is January 1996 to August 2015.

	Front							Front Delta-Hedged							Back							Back Delta-Hedged						
Day	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min
-20	5.52	8.33	0.66	3.82	2.21	-6.20	-17.25	4.11	6.53	0.63	3.75	2.28	-3.75	-11.75	0.42	6.58	0.06	-1.17	-0.95	-5.94	-16.39	-0.67	4.65	-0.14	-1.42	-1.24	-6.79	-12.89
-19	2.65	14.67	0.18	-0.34	-0.11	-7.97	-35.80	1.06	11.81	0.09	-0.41	-0.14	-7.51	-30.10	-0.34	7.83	-0.04	-2.32	-1.77	-6.43	-19.08	-1.56	5.80	-0.27	-2.59	-1.94	-6.99	-15.58
-18	4.92	10.53	0.47	2.05	0.77	-7.51	-26.25	2.55	8.37	0.30	1.72	0.70	-6.25	-21.04	0.76	5.88	0.13	-1.25	-1.07	-5.13	-11.19	-0.87	4.06	-0.21	-1.63	-1.53	-5.13	-8.20
-17	6.43	8.40	0.77	4.01	2.02	-7.91	-20.46	3.61	7.06	0.51	3.17	1.61	-5.38	-15.98	0.81	4.90	0.17	-0.98	-1.14	-4.64	-9.71	-0.93	3.23	-0.29	-1.49	-1.80	-4.70	-6.76
-16	7.09	7.16	0.99	5.26	2.58	-9.60	-22.22	4.35	6.23	0.70	4.50	2.42	-6.28	-17.87	0.80	4.95	0.16	-0.89	-0.86	-5.33	-12.75	-0.76	3.24	-0.24	-1.24	-1.40	-6.43	-9.61
-15	5.70	8.67	0.66	3.66	2.32	-8.03	-23.43	3.19	7.31	0.44	2.73	1.51	-5.91	-19.07	0.04	5.39	0.01	-1.48	-1.88	-4.82	-12.41	-1.43	3.56	-0.40	-2.01	-2.26	-5.88	-9.48
-14	6.14	7.69	0.80	4.27	3.10	-7.70	-19.01	3.05	6.48	0.47	2.99	1.85	-5.31	-14.91	0.71	4.66	0.15	-0.80	-1.31	-4.47	-10.77	-1.06	2.95	-0.36	-1.51	-2.13	-5.47	-8.05
-13	7.60	5.00	1.52	6.27	5.49	-6.61	-12.81	4.97	4.56	1.09	5.73	4.95	-1.61	-7.82	0.37	4.28	0.09	-1.09	-1.40	-4.20	-8.58	-1.17	2.71	-0.43	-1.45	-2.10	-5.43	-6.42
-12	7.55	5.45	1.39	6.04	5.85	-6.87	-12.89	4.17	5.00	0.83	4.73	3.57	-2.35	-8.91	0.06	4.58	0.01	-1.55	-2.19	-4.47	-10.31	-1.66	3.03	-0.55	-2.12	-2.48	-5.11	-7.78
-11	7.16	7.27	0.98	6.46	4.29	-10.27	-23.27	5.14	6.47	0.79	5.41	3.58	-6.95	-19.08	-0.36	3.94	-0.09	-0.98	-2.00	-3.37	-6.51	-1.46	2.47	-0.59	-1.58	-2.92	-3.27	-4.19
-10	8.98	3.29	2.73	8.32	12.31	-7.40	-9.29	6.20	4.10	1.51	7.22	7.94	-0.91	-6.27	0.49	3.15	0.16	-0.40	-0.80	-2.92	-5.53	-0.82	1.88	-0.44	-0.82	-1.82	-3.44	-4.30
-9	8.04	4.35	1.85	7.90	9.08	-7.01	-10.43	6.81	4.73	1.44	7.18	7.65	-1.54	-6.85	-0.67	3.33	-0.20	-0.92	-1.93	-2.92	-5.40	-1.27	1.88	-0.68	-1.30	-2.69	-2.69	-3.15
-8	7.50	4.98	1.51	7.35	7.12	-7.43	-13.38	6.27	4.98	1.26	6.61	6.35	-2.15	-9.53	-1.11	3.31	-0.34	-1.33	-2.73	-2.48	-4.60	-1.69	1.80	-0.94	-1.68	-3.60	-2.68	-3.35
-7	8.21	3.57	2.30	7.69	8.90	-5.03	-7.49	6.31	4.43	1.42	7.17	8.05	0.03	-3.34	-1.12	3.24	-0.34	-1.77	-3.30	-2.77	-5.27	-1.86	1.70	-1.10	-1.93	-4.32	-2.83	-3.02
-6	7.44	5.55	1.34	6.27	4.08	-7.17	-13.27	4.23	5.26	0.80	5.25	3.58	-1.72	-8.17	-1.09	3.24	-0.34	-2.15	-3.80	-3.28	-6.12	-2.34	1.85	-1.27	-2.51	-5.09	-3.78	-3.72
-5	7.70	5.06	1.52	6.57	4.67	-6.40	-11.50	4.47	4.95	0.90	5.34	3.62	-1.33	-7.16	-1.54	3.18	-0.48	-2.51	-4.67	-2.67	-5.29	-2.71	1.82	-1.49	-2.94	-5.96	-3.08	-3.36
-4	8.69	3.11	2.80	7.93	10.48	-4.25	-5.16	5.22	4.14	1.26	6.47	8.01	-0.14	-2.91	-1.09	2.39	-0.46	-1.90	-4.99	-2.04	-3.64	-2.29	1.23	-1.86	-2.42	-6.96	-2.30	-2.26
-3	6.61	6.67	0.99	5.51	3.23	-6.20	-14.37	4.17	6.01	0.69	4.77	3.18	-1.36	-8.59	-2.67	2.96	-0.90	-3.40	-7.28	-3.10	-5.62	-3.58	1.88	-1.90	-3.78	-7.99	-3.87	-4.16
-2	5.10	8.87	0.57	5.15	2.80	-7.90	-25.05	5.11	7.52	0.68	4.95	3.09	-4.68	-19.12	-3.19	2.16	-1.47	-3.13	-9.76	-1.68	-2.78	-3.26	1.13	-2.87	-3.25	-11.43	-1.90	-1.51
-1	6.60	6.92	0.95	6.24	4.24	-7.51	-18.55	5.00	6.62	0.76	5.31	3.57	-3.35	-13.81	-3.13	1.64	-1.91	-3.26	-10.15	-2.39	-2.76	-3.34	1.05	-3.18	-3.36	-10.98	-2.85	-2.16

Table 3.4

Factor Exposures and Alphas from Shorting Front-Month OTM Put Options Two Weeks Before Maturity

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options two weeks before maturity and holding them to expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that a one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. Column (1) considers a US equity model comprising the US market (MKT), size (SMB), value (HML), momentum (UMD), and betting-against-beta (BAB) factors for US equities obtained from Fama and French (1996) and Frazzini and Pedersen (2014). Column (2) considers the global asset pricing model from Asness et al. (2013) comprising the MSCI world index and the value everywhere (VALEW) and momentum everywhere (MOMEW) factors. Column (3) adds the traded liquidity factor of Pástor and Stambaugh (2003) to the equity model in Column (1). Columns (4) to (7) include the option-based factors Put-ATM, Put-OTM, Call-ATM, and Call-OTM from Agarwal and Naik (2004), representing the excess returns from shorting options on a calendar month basis. These factors are included one at a time because of their large correlations, and the market return is omitted because of its high correlation with the option factors. Model (8) includes the excess return on the CBOE Put index. Model (9) includes the excess return from shorting a portfolio of front-month OTM put options 20 trading days before maturity and holding it until the final settlement; this factor is denoted −20 days. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha_{\%}^{Ann}$	7.419***	8.193***	7.167***	6.668***	6.496***	8.078***	8.110***	6.835***	6.631***
	(6.689)	(9.362)	(5.792)	(4.905)	(4.592)	(7.686)	(7.746)	(5.806)	(5.018)
MKT	0.479***		0.456***						
	(3.862)		(4.108)						
SMB	0.184		0.177	0.218*	0.214*	0.282*	0.289*	0.192*	0.160
	(1.548)		(1.588)	(1.727)	(1.723)	(1.934)	(1.957)	(1.773)	(1.635)
HML	0.143		0.172	0.137	0.136	0.121	0.121	0.127	0.052
	(1.270)		(1.435)	(1.250)	(1.241)	(1.174)	(1.170)	(1.294)	(0.624)
BAB	0.081		0.048	0.035	0.033	0.047	0.044	0.011	-0.007
	(1.085)		(0.693)	(0.489)	(0.450)	(0.682)	(0.645)	(0.190)	(-0.172)
UMD	-0.029		-0.032	-0.054	-0.053	-0.102	-0.105	0.021	-0.058
	(-0.385)		(-0.462)	(-0.737)	(-0.733)	(-1.148)	(-1.180)	(0.426)	(-1.175)
MSCI		0.461***							
		(3.849)							
VALEW		-0.093							
		(-1.435)							
MOMEW		-0.126							
		(-1.041)							
Liquidity			0.191						
			(1.455)						
Put-ATM				0.445***					
				(3.519)					
Put-OTM					0.455***				
					(3.417)				
Call-ATM						-0.290***			
						(-3.356)			
Call-OTM							-0.279***		
							(-3.321)		
PUT								0.670***	
								(3.466)	
-20									0.678***
									(2.608)
$\bar{R}^2$	16.533	15.471	18.586	15.770	16.339	9.112	8.750	32.055	34.197
Observations	235	235	235	227	227	227	227	235	235

Table 3.5
Factor Exposures and Alphas from Shorting Front-Month OTM Put Options One Week Before Maturity

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options one week before maturity and holding them to expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that a one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. The factor definitions are provided in Table 3.4. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha^{Ann}_{\%}$	8.054***	8.228***	7.994***	7.724***	7.650***	8.636***	8.658***	7.772***	7.600***
	(10.663)	(11.094)	(10.033)	(9.114)	(8.851)	(12.447)	(12.504)	(8.919)	(8.431)
MKT	0.292***		0.286***						
	(3.000)		(3.075)						
SMB	0.055		0.054	0.074	0.073	0.116	0.120	0.064	0.042
	(0.562)		(0.535)	(0.775)	(0.763)	(1.260)	(1.318)	(0.729)	(0.472)
HML	0.162**		0.169**	0.178**	0.176**	0.168**	0.168**	0.149**	0.107*
	(2.286)		(2.309)	(2.533)	(2.523)	(2.483)	(2.480)	(2.222)	(1.660)
BAB	-0.005		-0.013	-0.048	-0.050	-0.041	-0.043	-0.047	-0.059
	(-0.063)		(-0.152)	(-0.579)	(-0.597)	(-0.554)	(-0.576)	(-0.583)	(-0.764)
UMD	0.014		0.014	0.007	0.006	-0.023	-0.026	0.035	-0.005
	(0.219)		(0.218)	(0.122)	(0.095)	(-0.386)	(-0.427)	(0.648)	(-0.094)
MSCI		0.296***							
		(3.218)							
VALEW		0.045							
		(0.363)							
MOMEW		-0.004							
		(-0.028)							
Liquidity			0.045						
			(0.490)						
Put-ATM				0.288***					
				(3.183)					
Put-OTM					0.284***				
					(3.153)				
Call-ATM						-0.189***			
						(-3.216)			
Call-OTM							-0.181***		
							(-3.322)		
PUT								0.371**	
								(2.450)	
-20									0.401**
									(2.234)
$\bar{R}^2$	8.385	9.028	8.210	10.014	9.784	5.122	4.843	14.926	18.217
Observations	235	235	235	227	227	227	227	235	235

Table 3.6

Factor Exposures and Alphas from Shorting Front-Month OTM Put Options One Day Before Maturity

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options one day before maturity and holding them to expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that an one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. The factor definitions are provided in Table 3.4. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha^{Ann}_{\%}$	5.630***	5.436***	5.320***	6.048***	5.909***	7.554***	7.591***	5.155**	3.973**
	(2.931)	(2.910)	(2.655)	(3.833)	(3.614)	(6.594)	(6.670)	(2.482)	(2.199)
MKT	0.581**		0.553**						
	(2.470)		(2.414)						
SMB	0.074		0.065	0.144	0.141	0.212*	0.220*	0.097	-0.005
	(0.672)		(0.629)	(1.395)	(1.382)	(1.805)	(1.843)	(1.179)	(-0.083)
HML	0.099		0.135	0.222	0.220	0.207*	0.207*	0.070	-0.021
	(0.580)		(0.831)	(1.643)	(1.630)	(1.740)	(1.745)	(0.409)	(-0.132)
BAB	0.077		0.037	-0.097	-0.100	-0.083	-0.085	-0.006	-0.043
	(0.441)		(0.200)	(-0.911)	(-0.931)	(-0.944)	(-0.976)	(-0.038)	(-0.297)
UMD	0.080		0.077	0.057	0.056	0.010	0.006	0.109	0.090
	(0.862)		(0.902)	(0.656)	(0.643)	(0.116)	(0.075)	(1.371)	(1.267)
MSCI		0.632***							
		(2.698)							
VALEW		0.213							
		(1.132)							
MOMEW		0.247							
		(1.109)							
Liquidity			0.234						
			(1.560)						
Put-ATM				0.476***					
				(2.655)					
Put-OTM					0.474***				
					(2.597)				
Call-ATM						-0.325***			
						(-3.378)			
Call-OTM							-0.315***		
							(-3.427)		
PUT								0.695**	
								(2.178)	
-20									1.130***
									(3.893)
$\bar{R}^2$	5.673	7.991	6.608	10.444	10.378	5.412	5.170	10.027	30.115
Observations	235	235	235	227	227	227	227	235	235

Table 3.7

Distribution of Excess Returns from Selling OTM Put Options at the Beginning and at the End of the Cycle

This table summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at mid-prices. Positions opened between 20 and 11 trading days before maturity are closed ten days before maturity, while positions opened between ten days and one day before maturity are held until maturity for front-month options and closed on the evening preceding the expiration of the front month for back-month options. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, skewness, and the worst return during the sample period. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The sample period is January 1996 to August 2015.

	Front							Front Delta-Hedged							Back							Back Delta-Hedged						
Day	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min
-20	3.25	4.14	0.78	2.83	3.35	-6.36	-11.49	3.14	2.79	1.13	2.86	3.81	-7.26	-8.42	1.25	2.53	0.50	0.99	2.51	-3.59	-5.62	1.14	1.40	0.82	0.97	2.83	-4.69	-3.53
-19	2.93	4.40	0.66	2.23	2.40	-6.70	-12.33	2.51	3.01	0.83	2.18	2.66	-7.57	-9.18	1.25	2.55	0.49	0.81	1.98	-3.86	-5.48	0.93	1.44	0.64	0.73	2.05	-4.81	-3.39
-18	2.98	3.74	0.80	1.92	2.32	-5.70	-9.39	2.34	2.40	0.97	2.00	2.65	-6.26	-6.54	1.39	2.30	0.61	0.70	1.81	-3.49	-4.60	0.90	1.22	0.74	0.67	1.94	-4.47	-2.72
-17	2.39	3.56	0.67	1.41	2.17	-4.82	-8.28	1.64	2.15	0.76	1.36	2.39	-5.90	-5.62	1.07	2.16	0.49	0.41	1.29	-3.06	-4.33	0.55	1.04	0.53	0.33	1.32	-4.73	-2.55
-16	2.18	3.14	0.69	1.43	2.86	-3.44	-6.46	1.47	1.66	0.89	1.30	3.20	-4.35	-4.22	0.88	2.02	0.44	0.36	1.27	-2.47	-3.71	0.40	0.90	0.44	0.23	1.12	-4.54	-2.37
-15	1.63	3.45	0.47	1.05	1.73	-4.17	-7.05	0.99	2.06	0.48	0.73	1.40	-5.01	-4.81	0.70	2.02	0.35	0.35	1.26	-2.78	-3.34	0.29	0.97	0.30	0.13	0.59	-4.43	-2.04
-14	1.78	2.83	0.63	1.14	2.48	-3.51	-6.05	0.72	1.55	0.46	0.66	1.62	-4.50	-4.04	0.83	1.70	0.49	0.41	1.92	-1.94	-2.59	0.17	0.72	0.24	0.10	0.62	-3.26	-1.45
-13	0.54	3.35	0.16	-0.36	-0.58	-4.20	-6.46	-0.18	1.95	-0.09	-0.39	-0.70	-5.42	-4.41	0.26	1.76	0.15	-0.27	-1.05	-2.70	-3.07	-0.21	0.83	-0.25	-0.35	-1.53	-4.34	-1.89
-12	0.70	2.09	0.34	0.09	0.36	-1.96	-2.79	-0.02	0.95	-0.02	-0.07	-0.28	-2.01	-1.52	0.20	1.31	0.15	-0.19	-1.37	-1.39	-1.59	-0.23	0.54	-0.42	-0.30	-2.18	-2.32	-0.83
-11	-0.37	2.09	-0.18	-0.28	-1.08	-3.20	-4.40	-0.47	1.09	-0.43	-0.47	-2.19	-5.52	-3.09	-0.29	1.10	-0.26	-0.23	-1.72	-1.91	-1.89	-0.34	0.48	-0.71	-0.34	-3.51	-3.17	-1.10
-10	9.19	3.07	3.00	8.57	13.52	-7.57	-8.74	6.75	3.55	1.90	7.57	9.47	-1.37	-6.09	2.93	2.28	1.28	2.21	8.21	-2.31	-2.88	1.68	1.21	1.38	1.75	6.27	-1.55	-1.33
-9	8.35	3.96	2.11	8.22	10.35	-7.01	-9.44	7.16	3.94	1.82	7.43	8.93	-1.97	-6.20	1.82	2.69	0.68	1.61	4.50	-2.88	-4.23	1.28	1.41	0.91	1.28	3.81	-2.76	-2.21
-8	7.87	4.49	1.75	7.73	8.30	-7.28	-11.87	6.65	4.22	1.57	6.94	7.72	-2.76	-8.65	1.40	2.73	0.51	1.22	3.23	-2.52	-3.83	0.86	1.41	0.61	0.89	2.62	-2.50	-2.09
-7	8.60	3.17	2.72	8.14	10.59	-5.12	-6.63	6.75	3.56	1.89	7.40	9.41	-0.18	-2.59	1.57	2.41	0.65	1.05	3.00	-2.47	-4.40	0.78	1.18	0.66	0.78	2.65	-2.71	-2.38
-6	7.84	4.97	1.58	6.78	4.95	-7.15	-12.27	5.19	4.45	1.17	5.96	4.68	-2.37	-7.80	1.49	2.60	0.57	0.61	1.45	-3.25	-4.72	0.37	1.35	0.28	0.29	0.84	-3.88	-2.67
-5	8.14	4.46	1.83	7.15	5.72	-6.41	-10.23	5.47	4.13	1.32	6.08	4.86	-1.72	-6.70	1.41	2.37	0.60	0.65	2.02	-2.49	-3.48	0.30	1.13	0.27	0.20	0.72	-2.98	-2.26
-4	8.97	2.81	3.19	8.29	11.98	-4.23	-4.58	6.33	3.29	1.93	7.24	10.40	0.01	-1.83	1.39	1.93	0.72	0.71	2.76	-1.93	-2.56	0.33	0.86	0.38	0.25	1.27	-2.00	-1.39
-3	7.28	5.67	1.29	6.34	4.40	-6.05	-12.08	5.15	4.97	1.04	5.52	4.27	-1.98	-7.81	0.62	1.99	0.31	0.07	0.24	-2.07	-2.77	-0.20	0.94	-0.22	-0.31	-1.42	-2.57	-1.56
-2	6.16	7.07	0.87	6.20	4.27	-7.21	-19.44	5.99	5.93	1.01	5.88	4.62	-4.58	-14.84	-0.18	1.74	-0.11	-0.14	-0.61	-1.77	-2.14	-0.26	0.80	-0.32	-0.26	-1.52	-2.15	-1.01
-1	7.52	5.39	1.39	7.23	6.37	-7.17	-14.42	6.49	4.87	1.33	6.68	5.94	-3.73	-10.71	0.02	1.22	0.02	-0.10	-0.63	-2.38	-1.83	-0.16	0.62	-0.26	-0.17	-1.33	-4.11	-1.20

Table 3.8
Distribution of Excess Returns from Selling OTM Put Options at the Beginning and at the End of the Cycle with Transaction Costs

This table summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All transaction are conducted at bid or ask prices. Positions opened between 20 and 11 trading days before maturity are closed ten days before maturity, while positions opened between ten days and one day before maturity are held until maturity for front-month options and closed on the evening preceding the expiration of the front month for back-month options. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, skewness, and the worst return during the sample period. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The sample period is January 1996 to August 2015.

	Front							Front Delta-Hedged							Back							Back Delta-Hedged						
Day	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min
-20	0.22	6.29	0.03	-0.47	-0.33	-8.11	-19.06	0.23	4.54	0.05	-0.25	-0.20	-9.19	-14.81	-0.97	3.23	-0.30	-1.36	-2.33	-4.38	-8.04	-1.12	2.07	-0.54	-1.39	-2.75	-5.48	-5.51
-19	0.41	5.73	0.07	-0.49	-0.39	-7.07	-16.20	0.02	4.04	0.01	-0.45	-0.41	-7.99	-12.45	-1.42	3.39	-0.42	-1.89	-3.14	-3.84	-6.59	-1.80	2.38	-0.76	-1.98	-3.60	-5.03	-5.58
-18	0.56	4.59	0.12	-0.73	-0.69	-6.10	-11.83	-0.20	3.06	-0.06	-0.66	-0.66	-6.92	-8.61	-0.82	2.75	-0.30	-1.65	-3.20	-3.79	-5.60	-1.37	1.59	-0.86	-1.69	-3.68	-4.89	-3.73
-17	-0.18	4.30	-0.04	-1.39	-1.76	-4.91	-10.30	-1.06	2.65	-0.40	-1.44	-2.01	-6.25	-7.28	-1.62	2.89	-0.56	-2.45	-5.05	-4.11	-7.06	-2.18	1.71	-1.28	-2.50	-6.14	-6.13	-5.21
-16	-0.47	3.70	-0.13	-1.44	-2.38	-3.30	-7.77	-1.31	2.06	-0.63	-1.60	-3.13	-4.39	-5.30	-1.51	2.59	-0.58	-2.20	-4.99	-3.67	-6.33	-2.03	1.43	-1.42	-2.32	-6.61	-6.58	-4.62
-15	-1.44	4.43	-0.32	-2.23	-2.69	-4.50	-9.46	-2.07	2.77	-0.75	-2.47	-3.49	-5.76	-6.77	-1.82	2.54	-0.72	-2.31	-5.19	-3.35	-4.89	-2.31	1.45	-1.59	-2.57	-6.66	-4.82	-3.38
-14	-1.18	3.75	-0.31	-2.01	-3.01	-4.28	-9.06	-2.33	2.20	-1.06	-2.49	-4.44	-5.87	-6.50	-1.55	2.12	-0.73	-2.05	-6.52	-2.18	-3.42	-2.31	1.16	-1.98	-2.40	-9.26	-3.35	-2.28
-13	-3.77	5.71	-0.66	-5.25	-3.82	-6.69	-16.11	-4.47	4.03	-1.11	-5.10	-4.12	-8.75	-13.16	-2.41	2.32	-1.04	-3.10	-7.22	-3.43	-5.08	-2.93	1.37	-2.14	-3.18	-8.03	-5.06	-3.80
-12	-3.05	2.79	-1.09	-3.83	-9.46	-2.12	-4.64	-3.88	1.55	-2.50	-3.98	-9.15	-2.79	-2.99	-2.56	1.77	-1.45	-3.07	-11.85	-1.74	-2.47	-3.01	1.00	-3.02	-3.15	-12.16	-2.62	-1.56
-11	-4.81	3.24	-1.48	-4.75	-8.67	-4.57	-7.97	-4.94	2.17	-2.28	-4.98	-10.04	-6.18	-6.28	-3.36	1.56	-2.16	-3.31	-13.42	-2.32	-2.58	-3.44	1.07	-3.22	-3.45	-15.23	-3.73	-2.61
-10	8.98	3.29	2.73	8.32	12.31	-7.40	-9.29	6.20	4.10	1.51	7.22	7.94	-0.91	-6.27	0.49	3.15	0.16	-0.40	-0.80	-2.92	-5.53	-0.82	1.88	-0.44	-0.82	-1.82	-3.44	-4.30
-9	8.04	4.35	1.85	7.90	9.08	-7.01	-10.43	6.81	4.73	1.44	7.18	7.65	-1.54	-6.85	-0.67	3.33	-0.20	-0.92	-1.93	-2.92	-5.40	-1.27	1.88	-0.68	-1.30	-2.69	-2.69	-3.15
-8	7.50	4.98	1.51	7.35	7.12	-7.43	-13.38	6.27	4.98	1.26	6.61	6.35	-2.15	-9.53	-1.11	3.31	-0.34	-1.33	-2.73	-2.48	-4.60	-1.69	1.80	-0.94	-1.68	-3.60	-2.68	-3.35
-7	8.21	3.57	2.30	7.69	8.90	-5.03	-7.49	6.31	4.43	1.42	7.17	8.05	0.03	-3.34	-1.12	3.24	-0.34	-1.77	-3.30	-2.77	-5.27	-1.86	1.70	-1.10	-1.93	-4.32	-2.83	-3.02
-6	7.44	5.55	1.34	6.27	4.08	-7.17	-13.27	4.23	5.26	0.80	5.25	3.58	-1.72	-8.17	-1.09	3.24	-0.34	-2.15	-3.80	-3.28	-6.12	-2.34	1.85	-1.27	-2.51	-5.09	-3.78	-3.72
-5	7.70	5.06	1.52	6.57	4.67	-6.40	-11.50	4.47	4.95	0.90	5.34	3.62	-1.33	-7.16	-1.54	3.18	-0.48	-2.51	-4.67	-2.67	-5.29	-2.71	1.82	-1.49	-2.94	-5.96	-3.08	-3.36
-4	8.69	3.11	2.80	7.93	10.48	-4.25	-5.16	5.22	4.14	1.26	6.47	8.01	-0.14	-2.91	-1.09	2.39	-0.46	-1.90	-4.99	-2.04	-3.64	-2.29	1.23	-1.86	-2.42	-6.96	-2.30	-2.26
-3	6.61	6.67	0.99	5.51	3.23	-6.20	-14.37	4.17	6.01	0.69	4.77	3.18	-1.36	-8.59	-2.67	2.96	-0.90	-3.40	-7.28	-3.10	-5.62	-3.58	1.88	-1.90	-3.78	-7.99	-3.87	-4.16
-2	5.10	8.87	0.57	5.15	2.80	-7.90	-25.05	5.11	7.52	0.68	4.95	3.09	-4.68	-19.12	-3.19	2.16	-1.47	-3.13	-9.76	-1.68	-2.78	-3.26	1.13	-2.87	-3.25	-11.43	-1.90	-1.51
-1	6.60	6.92	0.95	6.24	4.24	-7.51	-18.55	5.00	6.62	0.76	5.31	3.57	-3.35	-13.81	-3.13	1.64	-1.91	-3.26	-10.15	-2.39	-2.76	-3.34	1.05	-3.18	-3.36	-10.98	-2.85	-2.16

Table 3.9

Distribution of Excess Returns from Selling OTM Put Options for a Single Day

This table summarizes the distribution of excess returns of portfolios of front-month and back-month OTM put options as a function of the point during the cycle that the positions are opened, measured as the number of days before the maturity of the front-month contract. All positions are held for a single trading day, and all transaction are conducted at mid-prices. For each day before maturity and for both the front and the back month, we report the annualized average return, return standard deviation, Sharpe ratio, alpha with respect to the Fama and French (1993) three-factor model, its t-statistic, skewness, and the worst return during the sample period. t-statistics are based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The sample period is January 1996 to August 2015.

	Front							Front Delta-Hedged							Back							Back Delta-Hedged						
Day	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min	Mean	Std	SR	α	t-α	Skw	Min
-20	-0.01	1.17	-0.01	0.09	0.53	-1.80	-1.59	0.20	0.59	0.33	0.18	1.41	-2.80	-1.12	-0.23	1.08	-0.21	-0.16	-0.83	-6.27	-3.43	-0.10	0.83	-0.12	-0.10	-0.55	-12.25	-3.35
-19	0.24	1.39	0.17	0.65	4.12	-3.60	-3.49	0.63	0.58	1.07	0.69	5.43	-4.30	-1.49	-0.29	1.01	-0.29	-0.05	-0.30	-2.38	-1.84	-0.04	0.64	-0.06	-0.03	-0.18	-6.57	-1.90
-18	0.39	1.13	0.35	0.28	1.67	-1.76	-2.00	0.44	0.51	0.87	0.42	3.45	-4.07	-1.30	-0.09	0.85	-0.11	-0.17	-1.19	-1.54	-1.35	-0.10	0.58	-0.17	-0.13	-1.02	-5.25	-1.45
-17	0.47	1.00	0.47	0.23	1.87	-0.99	-0.87	0.31	0.41	0.75	0.32	3.32	-0.88	-0.50	0.05	0.71	0.07	-0.13	-1.54	-0.58	-0.56	-0.06	0.32	-0.18	-0.07	-1.05	-1.85	-0.56
-16	-0.02	1.28	-0.01	-0.17	-1.14	-1.88	-1.93	0.04	0.54	0.08	0.00	0.01	-3.14	-1.19	-0.29	0.92	-0.32	-0.38	-3.21	-1.37	-1.19	-0.27	0.49	-0.56	-0.29	-3.23	-4.34	-1.16
-15	-0.00	1.23	-0.00	0.18	1.26	-1.89	-1.92	0.34	0.60	0.57	0.25	1.64	-3.11	-1.29	-0.40	0.99	-0.40	-0.30	-1.66	-3.97	-2.59	-0.20	0.74	-0.27	-0.26	-1.50	-9.71	-2.66
-14	0.47	1.68	0.28	0.56	3.13	-2.43	-2.88	0.26	0.75	0.35	0.25	1.37	-3.18	-1.62	0.02	1.09	0.02	0.06	0.46	-2.07	-1.78	-0.09	0.57	-0.16	-0.11	-0.92	-4.80	-1.47
-13	0.24	1.45	0.16	0.11	0.50	-1.67	-1.74	0.24	1.45	0.16	0.11	0.51	-1.67	-1.74	-0.03	0.91	-0.04	-0.11	-0.88	-0.89	-0.90	-0.13	0.38	-0.34	-0.17	-1.61	-1.70	-0.46
-12	0.90	1.26	0.71	0.21	1.14	-1.62	-1.82	0.22	0.54	0.40	0.28	2.14	-1.45	-0.74	0.30	0.96	0.31	-0.15	-0.78	-3.49	-2.42	-0.09	0.62	-0.14	-0.13	-0.76	-9.95	-2.31
-11	-0.37	2.09	-0.18	-0.28	-1.08	-3.20	-4.40	-0.47	1.09	-0.43	-0.47	-2.19	-5.52	-3.09	-0.29	1.10	-0.26	-0.23	-1.72	-1.91	-1.89	-0.34	0.48	-0.71	-0.34	-3.51	-3.17	-1.10
-10	1.21	1.76	0.69	0.59	2.60	-2.92	-3.70	0.41	0.91	0.45	0.46	2.38	-3.72	-2.30	0.28	1.13	0.25	-0.10	-0.59	-1.96	-1.74	-0.15	0.70	-0.22	-0.17	-1.07	-6.03	-2.06
-9	1.28	1.43	0.89	1.21	7.27	-2.90	-3.08	1.18	0.80	1.48	1.17	6.36	-3.32	-1.67	0.26	0.87	0.30	0.22	2.04	-2.46	-1.89	0.23	0.43	0.53	0.22	2.07	-4.71	-0.96
-8	-0.07	1.89	-0.04	0.27	1.21	-1.79	-2.57	0.41	0.79	0.52	0.43	2.50	-1.89	-1.32	-0.26	1.02	-0.25	-0.06	-0.56	-1.37	-1.40	-0.05	0.43	-0.11	-0.01	-0.10	-2.55	-0.71
-7	-0.57	2.29	-0.25	0.07	0.25	-3.04	-4.72	0.12	1.25	0.10	0.21	0.84	-5.42	-3.36	-0.47	1.06	-0.45	-0.16	-1.47	-1.56	-1.40	-0.14	0.49	-0.28	-0.08	-0.82	-3.57	-0.96
-6	0.01	2.31	0.01	-0.25	-0.70	-2.62	-3.40	-0.03	1.09	-0.03	-0.04	-0.15	-2.71	-1.74	-0.09	1.03	-0.09	-0.23	-1.70	-1.13	-1.09	-0.12	0.37	-0.32	-0.14	-1.52	-2.03	-0.54
-5	0.20	3.09	0.07	0.22	0.51	-4.42	-7.06	0.23	1.73	0.13	0.23	0.62	-5.38	-4.04	0.05	1.09	0.05	0.05	0.41	-1.92	-1.77	0.06	0.38	0.15	0.04	0.55	-1.96	-0.55
-4	2.24	2.61	0.86	1.97	4.69	-4.43	-5.65	1.26	1.49	0.84	1.36	3.49	-3.29	-3.25	0.62	1.11	0.56	0.47	3.64	-2.59	-1.93	0.22	0.44	0.50	0.24	2.48	-3.45	-0.99
-3	2.48	1.96	1.27	1.50	4.56	-2.13	-2.83	0.82	1.38	0.60	1.32	4.41	-1.08	-1.36	0.59	0.92	0.64	0.09	0.70	-0.87	-1.21	-0.04	0.42	-0.09	-0.03	-0.34	-2.58	-0.75
-2	1.75	2.68	0.65	2.10	4.72	-2.74	-4.15	2.05	1.90	1.08	1.90	4.59	-0.80	-2.00	-0.16	1.11	-0.15	0.00	0.03	-1.59	-1.53	-0.09	0.50	-0.18	-0.08	-0.76	-2.59	-0.82
-1	3.57	3.95	0.91	3.41	4.68	-5.02	-9.36	2.81	3.25	0.86	2.97	4.08	-2.66	-6.46	0.02	1.22	0.02	-0.10	-0.63	-2.38	-1.83	-0.16	0.62	-0.26	-0.17	-1.33	-4.11	-1.20

Table 3.10

Factor Exposures and Alphas from Shorting Front-Month OTM Put Options Two Weeks Before Maturity when Excluding FOMC Meetings

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options two weeks before maturity and holding them to expiration. We exclude the 41 months in which an FOMC meeting occurred less than one week before option expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that an one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. The factor definitions are provided in Table 3.4. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha_{\%}^{Ann}$	7.426***	8.027***	7.262***	6.887***	6.702***	8.367***	8.397***	7.090***	7.238***
	(6.796)	(8.222)	(5.933)	(5.028)	(4.683)	(7.982)	(8.038)	(6.340)	(5.501)
MKT	0.501***		0.490***						
	(4.068)		(4.339)						
SMB	0.131		0.129	0.174	0.171	0.224	0.231	0.172	0.163
	(1.140)		(1.140)	(1.454)	(1.452)	(1.585)	(1.606)	(1.455)	(1.407)
HML	0.094		0.104	0.095	0.091	0.105	0.105	0.105	0.058
	(0.866)		(0.893)	(0.923)	(0.901)	(0.946)	(0.943)	(0.984)	(0.602)
BAB	0.176**		0.161**	0.119	0.120	0.096	0.093	0.079	0.051
	(2.089)		(2.363)	(1.397)	(1.411)	(1.147)	(1.115)	(1.377)	(1.067)
UMD	0.009		0.008	-0.009	-0.010	-0.053	-0.057	0.026	-0.057
	(0.174)		(0.167)	(-0.175)	(-0.206)	(-0.867)	(-0.921)	(0.641)	(-1.346)
MSCI		0.476***							
		(3.888)							
VALEW		-0.035							
		(-0.743)							
MOMEW		0.013							
		(0.162)							
Liquidity			0.081						
			(0.910)						
Put-ATM				0.450***					
				(3.293)					
Put-OTM					0.456***				
					(3.198)				
Call-ATM						-0.281***			
						(-3.003)			
Call-OTM							-0.268***		
							(-2.969)		
PUT								0.588***	
								(3.722)	
-20									0.451**
									(2.238)
$\bar{R}^2$	19.170	17.342	19.281	16.944	17.426	7.827	7.338	29.332	18.501
Observations	194	194	194	188	188	188	188	194	194

Table 3.11

Factor Exposures and Alphas from Shorting Front-Month OTM Put Options One Week Before Maturity when Excluding FOMC Meetings

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options one week before maturity and holding them to expiration. We exclude the 41 months in which an FOMC meeting occurred less than one week before option expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that an one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. The factor definitions are provided in Table 3.4. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha_{\%}^{Ann}$	7.662***	7.654***	7.691***	7.523***	7.445***	8.486***	8.507***	7.515***	7.496***
	(9.802)	(9.548)	(9.791)	(9.029)	(8.763)	(11.862)	(11.886)	(8.069)	(7.518)
MKT	0.307***		0.309***						
	(2.935)		(3.079)						
SMB	0.016		0.016	0.044	0.043	0.076	0.081	0.043	0.034
	(0.130)		(0.133)	(0.378)	(0.376)	(0.658)	(0.703)	(0.398)	(0.302)
HML	0.135**		0.134**	0.160**	0.157**	0.167***	0.167***	0.141**	0.113*
	(2.055)		(2.024)	(2.481)	(2.447)	(2.715)	(2.717)	(2.145)	(1.667)
BAB	0.029		0.031	-0.025	-0.025	-0.038	-0.040	-0.030	-0.049
	(0.296)		(0.318)	(-0.245)	(-0.248)	(-0.393)	(-0.413)	(-0.298)	(-0.491)
UMD	0.039		0.039	0.037	0.033	0.010	0.008	0.042	0.001
	(0.576)		(0.578)	(0.576)	(0.525)	(0.166)	(0.127)	(0.725)	(0.012)
MSCI		0.321***							
		(3.274)							
VALEW		0.083							
		(0.566)							
MOMEW		0.073							
		(0.468)							
Liquidity			-0.014						
			(-0.179)						
Put-ATM				0.292***					
				(3.015)					
Put-OTM					0.284***				
					(2.952)				
Call-ATM						-0.192***			
						(-2.803)			
Call-OTM							-0.184***		
							(-2.883)		
PUT								0.331**	
								(2.200)	
-20									0.298
									(1.605)
$\bar{R}^2$	7.548	9.006	7.074	8.589	8.117	3.653	3.362	10.388	8.558
Observations	194	194	194	188	188	188	188	194	194

Table 3.12

Factor Exposures and Alphas from Shorting Front-Month OTM Put Options One Day Before Maturity when Excluding FOMC Meetings

This table reports the factor exposures and abnormal returns from shorting front-month OTM put options one day before maturity and holding them to expiration. We exclude the 41 months in which an FOMC meeting occurred less than one week before option expiration. Alphas are annualized and in percentage points. All regressors are normalized to unit variance, such that an one-standard-deviation increase in the regressor implies a change in the option portfolio return equal to the respective coefficient. The factor definitions are provided in Table 3.4. Inference is based on Newey and West (1987) standard errors with four lags (the closest integer to the fourth root of the number of observations as suggested by Greene (2012)). The adjusted R^2 is in percentage points. ***, **, * represent statistical significance at the 1%, 5%, and 10% level, respectively. The sample period is January 1996 to August 2015.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\alpha_{\%}^{Ann}$	5.457**	4.985**	5.230**	6.505***	6.368***	8.060***	8.094***	5.319**	4.278**
	(2.441)	(2.331)	(2.304)	(4.415)	(4.141)	(7.774)	(7.863)	(2.313)	(1.963)
MKT	0.609**		0.594**						
	(2.278)		(2.241)						
SMB	-0.030		-0.033	0.054	0.053	0.106	0.114	0.029	-0.035
	(-0.288)		(-0.310)	(0.602)	(0.592)	(0.985)	(1.034)	(0.325)	(-0.592)
HML	0.019		0.033	0.189	0.185	0.200	0.200*	0.025	-0.037
	(0.096)		(0.173)	(1.423)	(1.401)	(1.640)	(1.646)	(0.125)	(-0.191)
BAB	0.169		0.149	-0.052	-0.053	-0.074	-0.078	0.052	-0.009
	(0.826)		(0.710)	(-0.498)	(-0.499)	(-0.754)	(-0.787)	(0.287)	(-0.051)
UMD	0.131		0.129	0.128	0.123	0.084	0.080	0.121	0.096
	(1.464)		(1.522)	(1.422)	(1.375)	(1.172)	(1.141)	(1.260)	(1.081)
MSCI		0.666***							
		(2.581)							
VALEW		0.306							
		(1.543)							
MOMEW		0.437**							
		(2.014)							
Liquidity			0.112						
			(1.261)						
Put-ATM				0.472**					
				(2.465)					
Put-OTM					0.462**				
					(2.370)				
Call-ATM						-0.306***			
						(-3.041)			
Call-OTM							-0.295***		
							(-3.059)		
PUT								0.582*	
								(1.888)	
-20									0.954***
									(2.771)
$\bar{R}^2$	5.157	8.632	4.954	10.133	9.678	3.704	3.389	5.497	19.881
Observations	194	194	194	188	188	188	188	194	194

Table 3.13
Greeks and Implied Volatility of OTM Put Option Portfolios

This table reports the average implied volatility and Greeks of the option portfolios as a function of the number of days to expiration of the front-month contract. All Greeks are reported in absolute value. Gamma is multiplied by one thousand to improve readability, theta is reported in dollars per day, and vega represents the dollar change in the option price for a one percentage change in implied volatility. The sample period is January 1996 to August 2015.

	Front					Back				
Day	Delta	Gamma	Theta	Vega	Imp. Vol.	Delta	Gamma	Theta	Vega	Imp. Vol.
-20	0.16	3.09	0.39	0.67	0.27	0.19	2.46	0.32	1.16	0.25
-19	0.17	3.36	0.41	0.70	0.26	0.18	2.41	0.31	1.13	0.26
-18	0.16	3.24	0.44	0.63	0.27	0.18	2.35	0.32	1.07	0.26
-17	0.16	3.40	0.44	0.62	0.26	0.18	2.48	0.32	1.07	0.26
-16	0.16	3.47	0.44	0.60	0.26	0.18	2.47	0.32	1.06	0.26
-15	0.16	3.64	0.46	0.61	0.26	0.18	2.51	0.33	1.06	0.25
-14	0.16	3.78	0.47	0.59	0.26	0.18	2.52	0.33	1.05	0.26
-13	0.16	3.73	0.51	0.52	0.27	0.18	2.57	0.34	0.99	0.26
-12	0.16	3.94	0.53	0.52	0.27	0.18	2.61	0.35	0.99	0.26
-11	0.15	3.99	0.54	0.49	0.27	0.18	2.66	0.35	0.99	0.26
-10	0.16	4.24	0.56	0.48	0.26	0.18	2.73	0.35	0.98	0.26
-9	0.15	4.38	0.55	0.45	0.26	0.18	2.75	0.35	0.96	0.26
-8	0.15	4.62	0.66	0.39	0.28	0.18	2.75	0.37	0.91	0.26
-7	0.15	4.88	0.68	0.37	0.27	0.18	2.80	0.37	0.91	0.26
-6	0.16	5.39	0.75	0.35	0.27	0.19	2.95	0.39	0.92	0.25
-5	0.15	5.73	0.78	0.33	0.27	0.18	2.99	0.38	0.90	0.26
-4	0.15	5.90	0.81	0.29	0.27	0.18	3.02	0.39	0.89	0.25
-3	0.13	6.13	1.27	0.18	0.35	0.18	2.99	0.40	0.83	0.26
-2	0.12	7.28	1.56	0.15	0.35	0.17	3.01	0.40	0.80	0.26
-1	0.14	9.54	2.55	0.11	0.40	0.18	3.14	0.41	0.79	0.26

Table 3.14

Liquidity Measures of OTM Put Option Portfolios

This table reports a number of liquidity measures of the OTM put option portfolios as a function of the number of days to expiration of the front-month contract. The first two columns report the average daily volume and open interest of the strikes included in the portfolios in thousands of contracts. The next two columns report the aggregate volume and open interest (OI) of all strikes included in the portfolios, again in thousands of contracts. The last column reports the percentage bid-ask spread relative to the mid-price. The sample period is January 1996 to August 2015.

	Front					Back				
Day	Volume	Open	Volume Agg.	Open Agg.	$\frac{\text{Ask}-\text{Bid}}{\text{Price}}$	Volume	Open	Volume Agg.	Open Agg.	$\frac{\text{Ask}-\text{Bid}}{\text{Price}}$
-20	4.06	30.12	68.81	529.98	23.00	1.81	19.46	27.58	312.90	16.13
-19	4.86	31.23	78.55	554.84	19.90	1.73	19.56	27.09	318.91	17.06
-18	3.54	31.34	61.64	571.36	20.61	1.46	20.57	24.45	347.15	16.83
-17	3.73	33.22	60.90	580.63	21.09	1.52	19.95	26.18	340.09	17.16
-16	3.27	34.32	53.51	585.88	21.55	1.64	20.77	25.93	345.77	16.82
-15	3.38	33.93	54.52	579.28	21.64	1.67	20.98	27.80	367.90	17.20
-14	3.14	35.37	51.73	601.14	20.39	1.55	21.21	27.45	364.79	15.04
-13	3.09	34.21	52.75	578.64	23.62	1.57	21.46	27.81	374.70	16.95
-12	3.47	35.05	52.58	575.75	23.41	1.88	21.33	31.25	373.32	17.22
-11	3.33	35.56	51.60	575.91	24.78	1.89	21.88	33.54	391.18	17.59
-10	3.70	35.90	58.07	577.56	24.92	1.98	22.69	35.44	407.68	17.43
-9	4.06	35.95	63.01	560.74	27.23	2.11	23.04	36.34	403.70	18.27
-8	3.46	35.38	51.93	541.29	28.27	1.99	23.65	34.09	414.45	18.44
-7	3.76	35.08	54.90	514.69	29.34	2.21	23.37	38.66	408.95	18.32
-6	3.98	34.92	53.94	489.56	29.70	2.41	23.88	40.69	419.70	18.03
-5	3.94	34.39	51.37	474.95	30.57	2.46	24.33	41.22	426.16	18.31
-4	4.72	34.05	65.30	470.40	32.13	2.38	25.03	41.10	444.45	17.61
-3	4.46	34.12	59.44	463.65	37.32	2.58	25.14	45.71	442.76	19.08
-2	5.19	31.13	60.56	379.23	41.02	3.02	26.09	52.03	458.14	19.35
-1	6.48	30.58	69.19	338.86	44.49	4.09	26.49	74.56	482.09	19.36

Table 3.15

Liquidity Risk of OTM Put Option Portfolios

This table reports a number of liquidity risk measures of option portfolios at different points during the option cycle as a function of the number of days to expiration of the front-month contract. The first two columns report the cross-sectional average (Mean) and standard deviation (Std) of the percentage drop in trading volume compared to the previous trading day for those option contracts experiencing a drop. The next two columns report the cross-sectional average and standard deviation of the ratio of trading volume to open interest in percentage points. The last two columns report the cross-sectional average and standard deviation of percentage changes in the bid-ask spread from one day to the next. The sample period is January 1996 to August 2015.

	Front						Back					
	Volume(< 0)		Volume/Open		Change BAS		Volume(< 0)		Volume/Open		Change BAS	
Day	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
-20	65.05	24.87	19.90	24.95	18.28	75.84	70.46	24.10	28.22	74.04	9.11	40.77
-19	62.53	25.46	25.70	33.98	32.61	84.65	72.69	23.10	58.03	191.42	14.85	54.01
-18	66.20	26.23	15.11	18.41	31.84	83.56	71.91	25.18	57.97	154.62	14.13	45.22
-17	63.29	27.02	21.50	31.51	28.68	79.49	70.20	24.37	20.88	45.14	15.21	45.40
-16	61.25	27.37	18.37	22.48	29.93	81.89	70.45	23.35	17.77	34.52	12.89	46.84
-15	61.86	26.13	19.53	28.09	14.51	70.64	70.05	24.66	18.40	34.94	-2.41	43.23
-14	62.46	26.84	13.29	15.21	71.85	105.62	72.34	24.87	14.97	29.55	75.31	79.64
-13	63.51	27.26	15.21	21.97	36.51	79.64	70.76	23.82	17.09	35.70	30.20	63.86
-12	61.72	26.19	29.99	43.33	43.65	88.73	67.86	24.69	22.10	41.70	36.03	62.56
-11	61.78	26.15	31.05	51.41	40.10	87.84	68.77	25.16	19.45	36.65	33.48	62.88
-10	60.44	26.31	15.95	17.15	51.02	95.47	68.78	25.23	18.86	33.14	37.48	67.59
-9	58.62	26.45	17.42	18.89	39.06	91.13	69.67	25.50	19.02	36.74	17.92	58.71
-8	62.19	26.87	14.52	16.15	38.81	86.42	71.00	25.00	16.52	29.38	15.35	56.33
-7	57.93	26.57	16.66	19.93	31.16	77.85	67.32	26.56	15.46	26.95	15.78	58.49
-6	58.11	25.68	18.02	18.26	36.43	88.59	65.70	26.66	18.75	35.71	17.41	60.57
-5	55.45	25.13	18.46	18.59	43.78	98.76	67.01	26.53	21.29	37.90	15.63	58.87
-4	51.41	26.55	24.24	24.93	70.82	119.68	67.46	25.79	15.73	22.41	27.36	74.77
-3	56.30	25.97	20.59	19.71	77.25	131.32	66.61	25.93	25.03	44.34	22.19	66.00
-2	51.09	22.77	25.92	25.00	73.26	121.55	64.41	26.93	18.61	25.22	18.40	64.67
-1	48.64	20.24	31.77	24.26	154.64	168.12	55.65	23.99	32.63	61.07	23.47	76.43

3.6 Appendix

Option Return Computations

This appendix presents the formulas used to compute option returns in the different cases that can arise; we consider both long and short option positions and trades at mid-prices as well as accounting for transaction costs.

3.6.1 Return Computations at Mid-Prices

When transactions are conducted at mid-prices, the return on a long option position between t and $t+\tau$ is given by

$$R^L_{t+\tau} = \frac{P_{t+\tau} - P_t}{P_t}, \tag{3.1}$$

where P_t denotes the mid-price of the option at time t. The return on a short position is just the opposite of that on a long position:

$$R^S_{t+\tau} = -R^L_{t+\tau} = \frac{P_t - P_{t+\tau}}{P_t}. \tag{3.2}$$

In the special case where the options are held to expiration, the returns are computed by setting $P_{t+\tau}$ in these expressions equal to the option's final settlement value based on the special opening quotation of the underlying index (SET), i.e. $P_{t+\tau} = (SET - K)^+$ for calls and $(K - SET)^+$ for puts, where K denotes the strike price.

3.6.2 Return Computations at Bid-Ask Prices

When the returns are computed using bid and ask prices, the returns on a long position are given by

$$R^{L,BA}_{t+\tau} = \frac{P^B_{t+\tau} - P^A_t}{P^A_t}, \tag{3.3}$$

where P^A_t and P^B_t are the ask and bid prices, respectively. Intuitively, the position is entered at P^A_t, so $1/P^A_t$ options must be bought to obtain a unit dollar exposure.

Importantly, with transaction costs, the return on a short position is no longer the opposite of that on a long position. Rather, it is given by

$$R^{S,BA}_{t+\tau} = \frac{P^B_t - P^A_{t+\tau}}{P^B_t}. \tag{3.4}$$

In the special case where the options are held to maturity, the returns are computed by setting $P^A_{t+\tau}$ and $P^B_{t+\tau}$ in these expressions equal to the option's final settlement value based on the special opening quotation of the underlying index.

3.6.3 Return Computations with Bounds

If the option is not held to maturity and is not traded at the time the position is closed, we compute the returns based on price bounds obtained by no-arbitrage as detailed below. To ensure the robustness of the returns we document, we use the worst-case price, i.e. the lower price bound when holding a long position and the upper price bound when holding a short position.

In the case where transactions are conducted at *mid-prices*, the returns on a long and short position are given by

$$R^L_{t+\tau} = \frac{P^{LB}_{t+\tau} - P_t}{P_t} \tag{3.5}$$

and

$$R^S_{t+\tau} = \frac{P_t - P^{UB}_{t+\tau}}{P_t}, \tag{3.6}$$

respectively, where $P^{LB}_{t+\tau}$ and $P^{UB}_{t+\tau}$ denote the lower and upper price bounds computed using mid-prices, respectively.

When transactions are conducted at *bid and ask prices*, the returns on a long and short position are computed as

$$R^{L,BA}_{t+\tau} = \frac{P^{B,LB}_{t+\tau} - P^A_t}{P^A_t} \tag{3.7}$$

and

$$R^{S,BA}_{t+\tau} = \frac{P^B_t - P^{A,UB}_{t+\tau}}{P^B_t}, \tag{3.8}$$

respectively, where $P^{B,LB}_{t+\tau}$ is the lower bound computed from bid prices and $P^{A,UB}_{t+\tau}$ the upper bound computed from ask prices.

3.6.4 Price Bounds

We derive the bounds on the price of options that do not trade on a particular day using the prices of options with adjacent strike prices and the same maturity that do trade on that day. We expose the methodology for put options since they are the focus of our study; similar reasoning allows obtaining the price bounds for call options.

Consider a set of put options with strikes prices K_0, K_1, K_2, K_3, and K_4, with $K_i < K_{i+1}$ for $i \in [0, 1, 2, 3]$. Let P_i denote the corresponding put option prices. Assume that the option with strike K_2 does not trade on that day. We obtain the upper and lower bounds using the convexity of the option price in the strike price.

The upper bound for P_2 is computed from the straight line linking the prices of the options with strikes K_1 and K_3, i.e.

$$P^{UB}_2 = P_1 + \frac{P_3 - P_1}{K_3 - K_1}(K_2 - K_1). \tag{3.9}$$

The lower bound is obtained by drawing two straight lines based on the prices of the options with strikes K_0 and K_1 on the one hand, and K_3 and K_4 on the other, and taking the maximum of the two values:

$$P^{LB}_2 = \max\left(P_1 + \frac{P_1 - P_0}{K_1 - K_0}(K_2 - K_1), P_3 + \frac{P_4 - P_3}{K_4 - K_3}(K_2 - K_3)\right). \tag{3.10}$$

3.6.5 Computation of Delta-Hedged Returns

The computation of hedged returns follows Ziegler and Ziemba (2015). Hedging is assumed to be performed using futures, and the hedged return is the sum of the unhedged return and the payoff from the hedge, scaled by the initial option price.

For example, for a short position in put options, the hedged return when option transactions are conducted at mid-prices is given by

$$R_{t+\tau}^{S,H} = R_{t+\tau}^{S} + \Delta \frac{F_{t+\tau} - F_t}{P_t}, \tag{3.11}$$

where Δ denotes the option's delta and F_t the futures price.

Again for a short put position but in the case with transaction costs, the hedged return is

$$R_{t+\tau}^{S,BA,H} = R_{t+\tau}^{S,BA} + \Delta \frac{F_{t+\tau} - F_t}{P_t^B}. \tag{3.12}$$

Chapter 4

Leveraged ETPs Across Asset Classes

Adriano Tosi[1]

Abstract

Leveraged exchange traded products (LETPs) exhibit different monthly returns than their underlying geared exchange traded products (ETPs). The effect is known as LETP slippage. This paper studies LETP slippage across five asset classes: equity developed, equity emerging, commodity, fixed income and currency markets. High volatility asset classes show larger slippage than low volatility asset classes. In the cross-section, LETP slippage is more pronounced in instruments with high return variability. A portfolio of liquid and volatile LETPs yields risk-adjusted returns of 12.50% on an annual basis. Further, LETP slippage is either zero or negatively correlated with the same asset class ETP market portfolio. Accordingly, LETP slippage can be used as a diversification instrument when combined with a broad market index.

Keywords: Asset Pricing, Leveraged Exchange Traded Products, Volatility, Multi Asset Classes.

JEL Classification: G11, G12, G13, G14

[1] I thank Marlon Azinovic, Gazi Kabas, Steven Ongena and Alexandre Ziegler for helpful comments.

4.1 Introduction

Exchanged traded products (ETPs) constitute one of the most important financial market innovations of the past decades. In recent years, *leveraged* ETPs (LETPs) have become increasingly popular.[2] An article of *The Financial Times* "Worries over exotic exchange traded funds deepen", 14 February 2018, shows that there are over 800 LETPs with assets reaching 80 billion USD in 2017. Despite the popularity of LETPs, there are concerns about their divergence from the target return they track. The daily rebalancing of LETPs induces a return slippage over multiple days. LETP slippage is defined as the divergence in returns between a LETP and the corresponding underlying ETP with the same degree of leverage. For instance, selling a triple (3x) LETP and buying the corresponding ETP leveraged up three times yields a systematic spread over holding periods greater than one day. This behavior makes LETPs not always predictable. As a consequence, LETP issuers highlight this non-trivial characteristic in their prospectus. For instance, ProShares LETFs fact sheet points out the following.[3]

"... This leveraged ProShares ETF seeks a return that is 2x the return of its underlying benchmark (target) for a single day, [...], ProShares returns over periods other than one day will likely differ in amount and possibly direction from the target return for the same period. ***These effects may be more pronounced*** *in funds with larger or inverse multiples and* ***in funds with volatile benchmarks****. ..."* ProShares: Leveraged ETFs Website and Fact Sheet.

Consistent with financial press concerns and fact sheet warnings, academic research finds theoretical issues in the design of LETPs. Theoretical research shows that LETP returns should be negatively affected by the underlying asset volatility (Avellaneda and Zhang (2010)) and autocorrelation (Hessel et al. (2018)). These theoretical predictions are confirmed in the time series of returns of prominent US equity LETPs. Section 4.2 presents a literature review.

This paper investigates empirically LETP slippage across five different asset classes. The study covers: equity developed, equity emerging, commodity, fixed income and currency markets. The empirical findings show that high volatility asset classes exhibit larger slippage than low volatility asset classes. Within the cross-section of each asset class, LETP slippage is more pronounced in instruments which display high variability. Variability measures of the underlying ETP such as realized volatility, market beta, autocorrelation and the interaction of realized volatility and autocorrelation are prominent sorting variables. More generally, sorting measures that include some component of realized volatility have consistent and considerable selection ability. Intuitively, realized volatility is a variability measure that clusters and is persistent across time and securities.

These findings are more pronounced if LETPs are aggregate across asset classes and among the most liquid LETP securities. A portfolio of liquid and volatile LETPs yields CAPM risk-adjusted returns of 12.50% per annum, statistically significant at the 1% level. The sample period is 2009-2018.

Lastly, LETP slippage is either zero correlated or negatively correlated with the same asset class

[2]ETP products includes exchange-traded funds (ETFs), exchange-traded vehicles (ETVs) and exchange traded notes (ETNs). LETPs are derivative instruments that replicate a multiple of the daily underlying ETP return. The multiple can be double or triple leveraged, either with positive or negative exposure.

[3]http://www.proshares.com/funds/uym.html, as of September 2018.

ETP market portfolio. Suitably, LETP slippage can be used as a diversification instrument when combined with the same asset class broad market index. This study shows a portfolio diversification benefit from this combination. The portfolio advantage is in terms of standard deviation, ex-post CAPM beta exposure and Sharpe ratio. Despite the pitfalls of LETPs, LETP slippage could be used as a low-cost hedging instrument.[4]

The paper is structured as follows: Section 4.2 provides a literature review, Section 4.3 describes the data, Section 4.4 explains the methodology, Section 4.5 presents the empirical results and Section 4.6 concludes.

4.2 Literature Review

This paper contributes to the literature on LETPs. Researchers document both theoretically and empirically the pitfalls of LETPs. Conceptually, LETPs underperform the corresponding underlying ETPs geared up to the same amount of leverage over holding periods greater than one day.

In particular, Carver (2009) shows that the daily rebalancing of LETPs cause value deterioration of these instruments over sustained period of time. This decay may lead LETPs value toward zero. The effect becomes more severe in highly leveraged and volatile LETPs. Lu et al. (2012) show that double (2x) LETPs yield returns close to twice the underlying benchmark when the holding period is at most one month. However, the large return deviations between LETP and geared ETP is more conspicuous on holding periods of one quarter or one year. The LETP value deterioration increases both in the volatility and return autocorrelation of the underlying.

Avellaneda and Zhang (2010) derive a theoretical formula relating LETP behavior to the leverage multiplier and the underlying ETP realized variance. Their formula fits the empirical data especially well. They use 56 LETPs with quarterly data over the 2008 crisis period. Their results show that LETPs, as devised, display some drawbacks for buy and hold investors.[5] Guedj et al. (2010) report that retail investors hold LETPs for periods beyond three months, despite of their drawbacks. By doing so, they can lose 3% of their capital within 3 weeks and up to 50% on an annual basis. As a result, a different rebalancing mechanism, e.g. monthly rather than daily, would decrease holding costs. Similarly to Avellaneda and Zhang (2010), Little (2010) finds sizable value decline of LETPs during the convulsive 2008-2009 crisis period. They link this evidence to the inadequate daily rebalancing of LETPs. Besides underlying ETP volatility, Jarrow (2010) relates LETP slippage to funding costs.

Empirically, Dobi and Avellaneda (2012) document that LETPs have negative returns relative to their underlying ETPs geared up to the same amount of leverage. They define this effect as a LETPs

[4]In this study, all returns are excess returns, denominated in US dollars and computed at mid-price. The results of this paper do not take into account shorting borrowing fees of LETPs, which can vary between 0.5% and 5% on an annual basis. Regarding diversification benefits of LETPs, additional higher moment and gamma risks may be present in LETP strategies in specific market conditions.

[5]There is also a growing literature in the valuation of LETP options. Among others, Zhang (2010) shows that a LETP option can be replicated by a basket of underlying ETP options, by a relative value approach. In a related research, Leung and Sircar (2015) link theoretically the implied volatility of ETP options to that of the leveraged counterpart.

structural slippage. In their study, shorting LETPs to take advantage of the slippage is profitable and statistically significant for more than 75% of trades, even after taking into account borrowing rates. They use 21 LETPs pairs for the period 2009-2011. Besides long holding periods, they find that LETPs fail to behave as expected even at daily frequently. The systematic rebalancing of total return swaps within LETPs leads to a buy high and sell low mechanical effect that induces cumulative costs. Leung and Ward (2015) show that leveraged exposures to commodities can be achieved by means of futures rather than LETPs. They show that the former method has lower tracking error and bears less costs for buy and hold investors. A recent paper, Hessel et al. (2018), presents a pairs trading strategy between LETPs for the period 2007-2016. The study shows that selling LETPs with the same multiplier but with opposite leverage yields returns up to 12% on a yearly basis. Their empirical test is across six pairs of US LETPs. They show theoretically that the expected return of this strategy increases in the volatility of the underlying and how much the underlying is negatively autocorrelated.[6]

My paper complements LETPs literature along three dimensions. First, this empirical study shows that LETP slippage is larger in high volatility asset classes, e.g. equity and commodity rather than fixed income and currency. Second, my paper studies the cross-sectional pricing of LETPs by asset class. Within the most volatile asset classes, measures that include a component of realized volatility allow to identify LETPs that will exhibit larger slippage. Third, portfolios of LETPs can be used as diversification tool if combined with their same asset class broad market portfolio.

4.3 Data

This section presents the data used in the empirical analysis. Subsection 4.3.1 provides an overview about institutional information. Subsection 4.3.2 explains sample data.

4.3.1 Institutional Information

This paper considers ETPs and LETPs. ETPs include exchange traded funds (ETFs), exchange traded notes (ETNs) and exchange-traded vehicles (ETV). ETFs are portfolios of securities. They hold assets of the benchmark index and allow creation and redemption of fund shares. This mechanism leads share price and Net Asset Value (NAV) to be closely aligned by arbitrage capital (Ben-David et al. (2018)). By contrast, ETNs are unsecured debt obligations issued by a financial intermediary. Hence, ETNs are exposed to credit risk and track the underlying by market forces. The same holds for ETVs which comprises exchange traded commodities and currencies. In fact, ETVs track an underlying future or commodity by either synthetic replication or actual investment.

[6]There is a growing literature of VIX ETPs and LETPs. Alexander et al. (2015) provides a literature review of US and European volatility exchanged traded products that have grown in popularity as both hedging and speculative tools. Liu and Dash (2011) and Goltz and Stoyanov (2013) documents that ETFs and ETNs linked to VIX Futures behave differently than the spot VIX. Specifically, the ETPs have larger roll over loss than the spot VIX. Alexander and Korovilas (2012) analyze returns and risk characteristics of direct, leveraged and inverse VIX ETNs. Asensio (2013) documents the popularity of VIX ETPs across non-professional investors. Eraker and Wu (2017) rationalize with an equilibrium argument the large negative returns of VIX futures and VIX ETNs. Hancock (2013), Bordonado et al. (2017) and Kaeck (2018) examine the performance of direct and inverse volatility ETN and ETPs. They conclude that these instruments are more of a speculative use than an hedging one. See, most popular volatility ETPs `https://www.etf.com/channels/volatility-etfs`.

LETPs aim to reproduce a multiple (m) of a benchmark ETP return over a one-day horizon. The multiple can be either positive or negative and have a double or triple exposure. LETPs can be also merely inverse. LETPs achieve this multiple by means of borrowed capital, index swaps or other derivatives. LETPs split their capital in two parts. A first fraction is deployed in highly leveraged derivatives. A second fraction is invested in low duration debt products which are used as collateral. LETPs aim to keep a constant target leverage exposure of the benchmark. This induces LETPs to reblance their exposure daily.[7]

LETP rebalancing mechanism is described by regulatory authorities and academic researchers. U.S. Securities and Exchange Commission provides an intuitive explanation of LETPs rebalancing mechanism for retail investors.[8] Dobi and Avellaneda (2012) give a rigorous explanation of the mechanism by means of total return swaps. Both explanations are similar and they conclude that LETPs diverge from the performance of the underlying geared ETP over multiple days. Following these two sources, I provide a similar intuitive explanation of why LETPs fall short over a two-days period. Assume a double (2x) LETP tracks an ETP. The ETP has a value of 100 at day zero. LETP has own capital of 100 placed in cash and a total return swap (TRS) exposure of 200. If the ETP increases by 10% on day one and then decreases by 10% on day two, the ETP and LETP diverge in their supposed double exposure over a two days period. At day two ETP value is 99, while LETP own capital value is 96. Despite a drop of 1% in ETP, the LETP has a drop of 4% which is greater than a drop of 2% (2x) over a two days horizon. In fact, LETP instrument had to buy additional 20 units of TRS at day one and sell 24 units of TRS on day two to keep a constant leverage exposure at the end of each trading day. The systematic rebalancing is detrimental for LETPs.

4.3.2 Sample Data

The sample consists of LETP and ETP data from the Center for Research in Security Prices (CRSP) and ETF Global (ETFG) databases. CRSP and ETFG datasets are collected through WRDS. I consider only double and triple LETPs with positive or negative exposure. I select all LETPs and ETPs whose tickers are present in the industry file of the ETFG database. The ETFG industry file contains LETP and ETP information regarding: ticker, asset-class, development level, leverage multiplier and if the ETP is leveraged or un-leveraged. All selected instruments are US-listed. I merge the two databases by ticker. In addition, I collect daily and monthly return and volume data from CRSP. Daily Net Asset Value (NAV) per share and three-month average daily volume data are collected from ETFG. Monthly returns are in excess of one-month U.S. Treasury bill rate and expressed in USD. The risk free rate is collected from Kenneth French's website.[9]

Whenever possible, I use CRSP data as first choice. CRSP data covers about 74% and 89% of LETP and ETP instruments, respectively. For those products not available in CRSP, I use data from ETFG.

[7] In addition, LETPs may be less tax efficient than ETPs due to the short-term capital gains they produce. Furthermore, LETPs have larger fees and expenses than ETPs. ETFs bear taxes due to the frequent occurrence of dividends, whereas ETNs are taxed only on capital gains. For additional information on ETVs, see NYSE https://www.nyse.com/products/etp-funds-etv.

[8] https://www.sec.gov/investor/pubs/leveragedetfs-alert.htm

[9] http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

I find recording errors in ETFG datasets. The data provider confirms the recording errors, e.g. number of shares in place of NAV or formatting issues, as of February 2019. Whenever the ETFG dataset is used, I apply a recording error detection. I exclude extreme daily returns that are ten scaled median absolute deviations (MAD) away from the median, as suggested in Leys et al. (2013) and inline with the data filtering of Lee and Wang (2019). This screen induces a partial look ahead bias in the backtest, an issue well recognized also in other studies, e.g. (Asness et al. (2013), Daniel and Moskowitz (2016), Moreira and Muir (2017) and Lee and Wang (2019)). However, the conclusions of this paper are similar if I only use CRSP data. Additional procedures regarding data, methodology and robustness checks are discussed in Appendix 4.7.1.

This paper considers five different asset classes: equity developed markets, equity emerging markets, commodity, fixed income and currency. LETPs and ETPs are classified in these categories using the ETFG asset class and development level classifications. The sample period is from May 2008 to August 2018. The first year of the sample is used for portfolio construction and parameters estimation. Hence, LETP portfolio analysis ranges from May 2009 to August 2018. I restrict the portfolio analysis to the 2009-2018 period for three reasons. First, to compare equity and fixed income instruments over the same time range. Second, to have equity markets on similar time range as commodity and currency LETPs. Commodity and currency LETP portfolio analysis starts in December 2009.[10] Third, LETP strategies have performed exceptionally well in the 2008 crisis. Hence, the main analysis of this paper excludes 2008 crisis to put all asset classes on an equal foot. However, Appendix 4.7 reports the results including 2008 for equity markets. This robustness check confirms the results of the whole paper.

Table 4.7.1 provides a sample overview of LETP and ETP instruments by asset class. This table shows the full sample number of LETP and ETP instruments available. Panel A of Table 4.7.1 presents the total number of LETPs pooling together both double and triple absolute leverage multipliers ($m = 2, 3$), i.e. including LETPs with both positive and negative leveraged exposure. Table 4.7.1 also presents start and end date of the sample by asset class. By far, equity developed markets have the largest number of LETPs, 171. Commodity follows with 41 LETP. Then, equity emerging and fixed income have 26 LETPs each. Lastly, currency have 10 LETPs. Panels B and C of Table 4.7.1 presents the number of LETPs by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments with absolute multiplier m.

4.4 Methodology

This section presents the methodology adopted in this paper. Specifically, it describes the sorting measures, portfolio construction, and returns computation of LETP portfolios.

[10]Restricting LETP equity and fixed income sample period as for commodity and currency leads to similar conclusions. Along the same lines, restricting double and triple LETP samples on the same time range leads to the same conceptual conclusions as described in the paper.

4.4.1 Systematic Variability Measures

Within each asset class, I use four different sorting variables to select securities in the cross-section. The ranking measures are constructed from the underlying ETP market as it is standard in the literature (Hessel et al. (2018)).[11]

To begin with, I match LETP and underlying ETP instrument by maximum absolute correlation. Specifically, I compute LETP and ETP correlation for all instruments with daily returns over the year preceding the day of portfolio construction. Then, each LETP is paired to the ETP with which it exhibits the largest absolute correlation. I require an absolute correlation of at least 50% to form a pair.[12] Then, all the ranking measures are estimated with daily returns of the corresponding matched underlying ETP product over the twelve months prior to portfolio construction. The information set used to construct portfolios is lagged by one day.

Rather than finding the best possible sorting measures for each asset class, I use the simplest and most intuitive. All valuation measures have some component of variability. Conceptually, the more an ETP moves the larger the LETP slippage is. For this reason, I consider the following four sorting measures. (i) The first measure is realized volatility (σ). As outlined in LETPs prospectus, volatility is a prominent variable for LETPs. (ii) The second measure is the CAPM beta of the underlying ETP with respect to the same asset class market portfolio (β). Beta is estimated with a time-series regression. For each asset class, the equally weighted market portfolio is comprised of all ETP instruments available at the time of portfolio construction (as in Frazzini and Pedersen (2014)). Beta represents the systematic movement of an asset with respect to the market. Accordingly, the more sensitive an asset is to market moves, the larger the LETP slippage should be.[13] (iii) The third ranking measure is the first order autocorrelation (ρ_1). (iv) The fourth sorting measure is the interaction of σ and ρ_1, ($\sigma\rho_1$). Both the third and fourth measures are suggested by theory. Hessel et al. (2018) show theoretically that LETP slippage is affected both by autocorrelation and the interaction of volatility and autocorrelation. All the measures are constructed such that a higher value implies that the LETP should exhibit a larger slippage. Accordingly, ρ_1 is defined as minus the autocorrelation.

4.4.2 Portfolio Construction

Using the above sorting measures, I construct LETP portfolios to evaluate their slippage. Portfolios are rebalanced at the beginning of each month. To be included in a portfolio, any security must have: (i) at least 240 observations over the year preceding portfolio construction and (ii) data available on the day preceding portfolio construction. The first condition is necessary for matching LETP and ETP securities by correlation and to construct sorting measures. Furthermore, for each asset class, I require to have at least two LETPs to construct portfolios.

[11] Constructing equivalent sorting measures from LETP market leads to similar results.

[12] I use 50% absolute correlation value because LETP close to distress may temporary deviate in correlation from the ETP underlying product.

[13] I leave to future research the disentanglement of which fraction of LETP slippage is imputable to realized volatility and leverage constraint effect (beta anomaly), respectively.

Within each asset class, I use the following portfolio construction. Each month, I sell LETPs and take an offsetting position in the corresponding paired ETPs. The ETP position is geared up to the same leverage level as the LETP. The ETP long or short position depends on the sign of the correlation between LETP and ETP long positions. The ETP is bought (sold) if the correlation is positive (negative). The return of a LETP-ETP pair spread i is:[14]

$$r^{e}_{pair_i} = \mathrm{sign}(\rho_{LETP_i,ETP_i}) \cdot m \cdot r^{e,Long}_{ETP_i} - r^{e,Long}_{LETP_i} \tag{4.1}$$

Where $\mathrm{sign}(\cdot)$ is the sign function. ρ_{LETP_i,ETP_i} is the correlation of LETP_i and ETP_i long positions over the year preceding portfolio construction. m is the leverage multiplier in absolute terms, as delineated in the LETP contract. $r^{e,Long}_{ETP_i} = r^{Long}_{ETP_i} - r^f$ is the monthly ETP_i long excess return. $r^{e,Long}_{LETP_i} = r^{Long}_{LETP_i} - r^f$ is the monthly LETP_i long excess return. r^f is the monthly risk free rate. These monthly returns are from t to $t+1$ month. In practice, futures, contract for difference and leverage in the margin account can be used to gear up ETP positions. Alternatively, shorting both LETPs refereeing to the same underlying asset and with opposite multipliers can be used.

After that, I construct an unconditional portfolio as the equally weighted average of all the LETP-ETP pairs available in the cross-section. Further, I form sorted portfolios. LETPs and corresponding paired ETPs are sorted in descending order by one of the four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. I refer to these unconditional, high and low portfolios as LETP portfolios.

In order to investigate the diversification benefit of LETPs, I construct combinations of unconditional or high LETP portfolios with same asset class ETP market portfolio.[15] Namely, I construct portfolios which are 50% invested in one of the LETP portfolios and 50% invested in ETP market portfolio. I refer to this combination as a 50%-50% allocation.

4.5 Empirical Results

This section presents the empirical results. Subsection 4.5.1 quantifies LETP slippage as a function of the same asset class ETP realized volatility. Then, Subsection 4.5.2 investigates the cross-sectional properties of LETP slippage within each asset class. Subsection 4.5.3 considers LETPs aggregated in high and low volatility asset classes among the most liquid instruments. Lastly, Subsection 4.5.4 analyzes the potential use of LETP slippage as a diversification instrument.

4.5.1 Slippage and Volatility Across Asset Classes

This section investigates the slippage of unconditional LETP portfolios as a function of the realized volatility of the same asset class ETP market portfolio. If LETP slippage is higher in volatile environ-

[14] Estimating the hedging ratio by time series regressions make the results weaker. Hence, using institutional information leads to better hedging.

[15] The same asset class market portfolio of ETP instruments is the basket of securities used to compute the sorting betas. However, the ETP securities are held for an additional month over the holding period of LETP portfolios.

ments, we should see an increasing performance of unconditional LETP portfolios as a function of an asset class realized volatility. The data confirms this conjecture.

Panel A of Figure 4.1 shows the slippage of unconditional LETP portfolios as a function of the same asset class realized volatility over the full sample. Panel A shows a clear upward trend. The pattern in the data verifies the hypothesis that high volatility asset classes exhibits large slippage. As the figure shows in red, triple LETPs yield the largest slippage across the most volatile asset classes. Their returns cluster between 8% and 10% on an annual basis.

To further corroborate this empirical finding, I study the statistical significance of LETP slippage with respect to the same asset class ETP portfolio returns. I run capital asset pricing model (CAPM) time series regressions of LETP portfolio returns on same asset class ETP portfolio returns.[16] Then, the t-statistic of the risk-adjusted returns is shown as a function of the same asset class ETP portfolio realized volatility over the full sample. Panel B of Figure 4.1 reports the results. A consistent picture emerges once more, high volatility asset classes exhibit the most significant t-statistic reaching values of 5 and 6.[17] In contrast, low volatility asset classes show t-statistics hardly above 2. This implies that LETP portfolios perform better with respect to the underlying ETP market especially in those asset classes in which they have larger slippage.

Table 4.1 presents specific numerical value of this analysis by having a closer look at each asset class. Equity developed and emerging markets are known to be more volatile than fixed income markets. In fact, equity ETP portfolio realized volatility ranges between 12% and 18%, whereas fixed income ETP portfolio realized volatility is about 3% on an annual basis. Accordingly, I would expected larger performance of LETP portfolios in the first two markets than in the latter. This is confirmed in the data. Panel A of Table 4.1 shows performance metrics for LETP portfolios that use both double and triple leveraged instruments. Specifically, the equity market LETP portfolios exhibit annualized average returns (Sharpe ratios) ranging between 4.92% and 7.81% (1.43 and 1.92). In contrast, the fixed income LETP portfolio yields an annualized average return (Sharpe ratio) of 1.99% (0.65). The sample period is from 5/2009 to 8/2018. Similar discrepancy in performance between equity and fixed income markets is present if LETP portfolios use either double or triple absolute leverage multipliers. Panels B and C of Table 4.1 show the results, respectively. For instance, in double leveraged instruments, equity markets LETP slippage exhibits average returns (Sharpe ratios) varying between 3.70% and 5.02% (1.14 and 1.58) on an annual basis. By contrast, fixed income LETP portfolio exhibits annualized average return of 1.75% and a Sharpe ratio of 0.90. Similar pattern in the data is shown for commodity and currency markets for the period 12/2009 - 8/2018. In fact, commodity ETP portfolio annualized standard deviation is 13%, while currency ETP portfolio annualized standard deviation is 5%. The commodity market exhibits a slippage (Sharpe ratio) of 4.38% (1.04) on an annual basis when all the LETP are pooled together. On the other hand, the currency market shows only 0.49% (0.39) on an annual basis. This effect is also confirmed in the double LETPs in which the LETP portfolios have annualized aver-

[16] In a CAPM time-series regression, the single factor is the market factor of that specific asset class.

[17] Newey and West (1987) standard errors are used throughout the paper to account for heteroskedasticity and autocorrelation. The number of lags is chosen as the closest integer to the fourth root of the number of observations as suggested by Greene (2012).

age return of 2.97% (0.97) in the commodity market while only 0.60% (0.62) in the currency instruments.

In short, high (low) volatility asset classes exhibit large (small) LETP slippage. This pattern in the data is confirmed by annualized average returns, Sharpe ratios and statistical significance of risk-adjusted returns.

4.5.2 The Cross-Section of LETP Slippage by Asset Class

If unconditional LETP portfolios increase their performance as a function of realized volatility, a similar effect should be present in the cross-section. LETPs with higher variability should exhibit larger slippage across instruments. This section analyzes different portfolio strategies within each asset class cross-section. Specifically, LETPs and corresponding underlying ETPs are sorted in terciles by four variability measures: β, σ, $\sigma\rho_1$ and ρ_1.

4.5.2.1 Equity Developed

To begin with, I analyze the cross-section of LETP slippage in equity developed markets. Equity is the prime "risk-on" asset class. Accordingly, I would expect to find substantial cross-sectional variation in LETP slippage. The data confirms this hypothesis.

I consider a pooled sample of LETPs comprising both double and triple leveraged instruments. Panel A.1 (A.2) of Figure 4.2 presents annualized average returns (Sharpe ratios) of high tercile portfolios for the four different ranking measures. These panels also present the performance of unconditional LETP portfolio. Panel A.1 shows that high terciles sorted by β, σ, $\sigma\rho_1$ or ρ_1 lead to larger returns than the unconditional LETP basket. Specifically, the sorted baskets yield returns of 6%-7% p.a., while the unconditional basket yields returns of 4.92% p.a.. In addition, the Sharpe ratio of all the strategies is substantial reaching at least 1.5 on an annual basis.[18] Panels B and C of Figure 4.2 split the sample in absolute leverage multiplier of 2 and 3, respectively. LETP portfolios with greater multipliers yield larger slippage. This effect is more pronounced in the cross-section when portfolios are sorted. Terciles sorted by β and σ show annualized average returns of 11% in triple levered products. These two sorting measures are especially effective in selecting LETPs that will exhibit low or high expected returns, as Table 4.2 shows. The profitability of sorting by β is coherent with previous literature on the beta anomaly and leveraged constrained investors (Black (1972), Frazzini and Pedersen (2014), Jylhä (2018)). This literature claims that high beta asset exhibit low expected returns, thus, they should be shorted. Despite the selection ability and the substantial returns yielded by these sorting measures, it is an open question whether these returns are achievable after borrowing fees and transaction costs. See Bai and Collin-Dufresne (2019) regarding limit to arbitrage in CDS markets. I leave this question for future research.

Table 4.2 presents ex-post CAPM time-series regressions of high tercile portfolio returns on same asset class ETP market portfolio returns. The high tercile risk-adjusted returns are of the same economic magnitude as the raw returns and all statistically significant at the 10% level. These results hold

[18] Results for equity developed markets are robust to the inclusion of 2008 crisis as Table 4.7.2 shows.

for the different leverage multiplier subsamples. In addition, LETP portfolios exhibit either zero or negative ex-post CAPM beta. The negative beta exposure is present primarily among the triple levered ETPs instruments, with t-statistics of -3. This result implies that LETP portfolios could be used as a diversification instrument.

4.5.2.2 Equity Emerging

I then study the cross-section of LETP portfolio returns in equity emerging markets. Emerging markets are known to be volatile. Therefore, I would expect to see substantial returns in LETP terciles. This projection is confirmed in the data.

Panel A of Figure 4.3 presents annualized average returns and Sharpe ratios of LETP portfolios sorted by each of the four variability measures. This panel presents high tercile portfolios and unconditional LETP portfolio that make use of both double and triple leveraged instruments. Panel A.1 shows that the sorting measures used to rank portfolios can select LETP instruments that will present larger slippage than the unconditional basket. Specifically, the high tercile portfolios yield average returns (Shape ratios) of 8%-9% (1.1-1.3) on an annual basis. In contrast, the unconditional basket yields lower average return of 7.81%, but higher Sharpe ratio of 1.43.[19] Panels B and C of Figure 4.3 divide the sample in absolute leverage multiplier of 2 and 3, respectively. The largest slippage and cross-sectional variation is present in the triple leveraged products. Once more, β and σ are the most effective sorting measures. In this case, high tercile portfolios sorted by β and σ yield annualized average returns (Shape ratios) of 14%-16% (1.4-1.6). In contrast, the unconditional LETP basket yield returns (Sharpe ratio) of 10% (1.4).

Also in emerging markets, LETP portfolios exhibit negative correlation with respect to a broad market portfolio of same asset class ETPs. Table 4.3 presents CAPM time series regressions of LETP portfolio returns on same asset class ETP portfolio returns. The ex-post CAPM-β of LETP portfolios is negative and statistically significant at the 10% level for the triple levered ETP instruments. This implies that LETP portfolios are negative beta assets with positive expected return. This feature is rather unique. As a natural consequence, LETP portfolios could be used to diversify if combined with the underlying ETP market.

4.5.2.3 Commodity

After studying the systematic behavior of LETPs in equity markets, I analyze commodity markets. Commodity is a volatile asset class. As a result, I would expect substantial average returns in LETP portfolios. The data confirms this thought in the cross-section.

Panel A of Figure 4.4 presents the results by reporting annualized average returns and Sharpe ratios of LETP portfolios. This panel considers all double and triple LETPs. Panel A.1 of Figure 4.4 highlights the ability of β, σ, $\sigma\rho_1$ and ρ_1 to select LETPs that will show substantial slippage. Specifically, the high terciles of these sorts yield annualized average returns (Sharpe ratios) of 4.5%-8.0% (0.50-0.85).

[19] Results for equity emerging markets are robust if 2008 crisis is included as Table 4.7.3 shows.

Among these measures, σ and $\sigma\rho_1$ produce the best performance. By contrast, the unconditional basket exhibits an average return of 4.38%, but larger Sharpe ratio of 1.04. Panel B of Figure 4.4 considers only double LETP instruments. Sorting by β, σ and $\sigma \cdot \rho_1$ yields larger returns, of 3% to 5% p.a., than the unconditional basket, 2.97% p.a., whereas ranking by ρ_1 does not. Triple LETP instruments show large economic magnitude in their slippage, for the period 2013-2018. Panel C of Figure 4.4 presents the results. The four sorting measures select LETP instruments that exhibit a slippage (Sharpe ratio) of 10% to 23% (0.4 to 0.98) on an annual basis. On the other hand, the unconditional basket has a slippage of 15% (0.89).

Even though, most of the time, high tercile portfolios yield larger returns than the unconditional LETP basket, they do not show a stable Sharpe ratio. Further, high tercile portfolios do not necessarily exceed the low tercile portfolio, e.g. for ρ_1 as Table 4.4 presents. While I cannot perfectly pin down an explanation, it seems that commodity alike LETPs may be either hard to hedge by underlying ETP instruments or have some sudden structural change in their systematic variability.[20]

Lastly, in commodity markets, LETP portfolios across all leverage multipliers and subgroups exhibits a market neutrality with respect to their ETP market portfolio. Table 4.4 presents CAPM time series regression results. Differently from the equity market, the commodity LETP high tercile portfolios do not have a statistically significant negative exposure to the underlying ETP market.

4.5.2.4 Fixed Income

After analyzing high volatility asset classes, I move to low volatility asset classes. Fixed income is known to be a safe haven asset class with low volatility relative to equity. Accordingly, I would expect to find a low economic magnitude in their cross-sectional slippage.

Panel A of Figure 4.5 presents the results of double and triple LETPs pooled together. Panel A.1 shows low economic magnitude across high tercile portfolios. Both sorted LETP portfolios and unconditional portfolios do not yield returns (Sharpe ratios) exceeding 2.73% (0.65) on an annual basis. It is an open question whether these minimal returns are existent only due to limits to arbitrage driven by excessive borrowing fees. By splitting the sample in double and triple leverage ETPs the qualitative conclusions do not change. Fixed income LETP slippage is small independent of the type of sort variable. The largest slippage reaches 2.55% (3.20%) in high terciles on an annual basis for the double (triple) instruments, as Panel B (C) of Table 4.5 presents.

In contrast to the equity markets, LETP portfolios are not always market neutral in fixed income markets. For instance, the pooled double and triple LETP portfolios can exhibit ex-post CAPM-βs of about one which are statistically significant at the 10% level. Table 4.5 reports the results.

[20] Other LETP portfolio examples of substantial slippage, relatively low Sharpe ratio and hard to hedge instruments are: gold miners, junior gold miners, silver producers and VIX LETPs spreads.

4.5.2.5 Currency

This subsection investigates LETPs in currency markets. Foreign exchange spot rates have low volatility relative to equity. Accordingly, I expect little or no slippage in LETPs both unconditionally and in sorted portfolios. The data confirms this thesis.

Figure 4.6 presents LETP unconditional and high tercile portfolio analysis. Sorting does not enlarge the low slippage exhibited by unconditional portfolio. By considering double and triple LETP instruments together, there is no clear pattern in high tercile portfolios. Their slippage does not even reach 1% on an annual basis. Panel A of Table 4.6 presents the results. Splitting the sample in double and triple LETP does not change the qualitative conclusions of this analysis. Specifically, the slippage reaches at most 1.2% on a yearly basis. Panels B and C of Table 4.6 show the results.

To summarize the results up to this point, LETPs exhibit substantial slippage and Sharpe ratio in equity developed, equity emerging and commodity markets. These asset classes are known to have substantial volatility. Sorting LETP portfolios by variability measures can increase annualized average returns in high tercile portfolios. The most consistently performing measures are σ and β. These sorting measures are persistent and clustering both in time and across securities. These characteristics imply a consistent selection of LETP instruments that systematically under perform relatively to the underlying ETP market. In contrast, low volatility asset classes such as fixed income and currency exhibit low slippage both unconditionally and conditionally.

4.5.3 Leveraged ETPs in High and Low Volatility Asset Classes

The results so far reveal larger LETP slippage in asset classes known to have high volatility, i.e. equity and commodity. The slippage is even more pronounced for LETPs whose underlying ETP has high variability relative to its asset class. However, if LETP slippage is systematically present in the data, it should be even more conspicuous at the macro level and among the most liquid securities.

To address these concepts, I add two steps in the portfolio construction. First, I pool equity developed, equity emerging and commodity LETPs together. I denote this pooled set of assets as the *high* volatility asset classes category. On the other hand, the *low* volatility asset class category is defined as pooling together fixed income and currency LETPs. Then, within each category, I select the top 50% most liquid LETPs in the cross-section. The liquidity measure is defined as the LETP average daily volume over the three months preceding portfolio construction.[21] After this, LETPs and corresponding ETPs are aggregated in portfolios either unconditionally or in sorted terciles. The remaining portfolio construction is kept as in the previous analysis.

4.5.3.1 High Volatility Asset Classes

Figure 4.7 presents the results for high volatility asset classes. This figure shows annualized average returns and Sharpe ratios of LETP strategies. Panel A of Figure 4.7 reports results for both double

[21] The liquidity measure is defined in this way because ETFG provides this measure for its set of data. However, the liquidity screen is robust to keeping only CRSP data and screening for the average daily volume over the last 2 to 4 months with 1 month increment.

and triple LETPs pooled together. There is a clear pattern in the data. The most liquid LETPs aggregated in an unconditional portfolio do deliver high slippage of 6.52% on an annual basis. High tercile portfolios yield even higher returns when sorted by β, σ, $\sigma\rho_1$ and ρ_1. The annualized average returns (Sharpe ratios) of these portfolios range between 7.8% and 11% (1.4 and 2). Panels B and C of Figure 4.7 split the LETP sample in double and triple LETPs, respectively. Splitting the sample leads to similar conclusions. LETP portfolios show considerable slippage in unconditional portfolios. Slippage increases when portfolios are sorted by the four variability measures. Specifically, triple LETP portfolios sorted by β or σ yield annualized average returns (Sharpe ratios) of 12%-14% (1.3-1.7) in high terciles.[22]

To further understand the return pattern in the data, I run time-series regressions of LETP portfolio returns on the ETP market portfolio returns. The ETP market portfolio comprises all equity and commodity ETP instruments available at portfolio construction. Table 4.7 reports the results. CAPM time series regressions show two effects. First, LETP portfolios yield risk-adjusted returns greater or equal to the raw returns. These alphas are statistically significant at least at the 10% level. Second, high volatility asset classes LETP portfolios exhibit negative or neutral exposure to the ETP market portfolio. CAPM-β estimates are predominantly negative. Both in LETP pooled sample as well as in the triple LETP sample these ex-post CAPM-β estimates are all negative and statistically significant at the 10% level for high tercile portfolios. As a result, LETP slippage could be used as a zero-cost hedging asset.

4.5.3.2 Low Volatility Asset Classes

This subsection discusses low volatility asset classes. This category of LETP portfolios show completely different patterns than high volatility asset classes. LETP portfolios do have small slippage, both unconditionally and conditionally. Panel A of Figure 4.8 shows that annualized average returns of low volatility asset classes do not exceed 4%. Panels B and C of Figure 4.8 split the sample in double and triple LETP portfolios, respectively. The qualitative conclusions of the analysis do not change in the two sub-samples. First, low volatility asset classes do not exhibit large slippage. Second, sorting portfolios by the four ranking measures does not necessarily increase the slippage in high terciles. To further highlight the difference between LETPs in high and low volatility asset classes, Figure 4.9 plots cumulative excess returns of these strategies. The Figure plots the high tercile portfolio sorted by σ. Independently from the leverage multiplier, Figure 4.9 shows that cumulative excess returns of high volatility asset classes exceed those of low volatility asset classes.

To further corroborate the different systematic behavior of LETPs in low volatility asset classes, Table 4.8 presents their ex-post CAPM-β estimates. These estimates are obtained by running time-series regressions of LETP portfolio returns on ETP market portfolio returns. ETP market portfolio comprises all fixed income and currency ETPs available at portfolio formation. LETP portfolios in low volatility asset classes are predominantly market neutral. Nonetheless, none of the portfolios is a negative beta asset. The market loadings are not statistically significant at the 10% level.

In short, high volatility asset classes in aggregate exhibit substantial slippage. This slippage is

[22] High volatility asset classes results are robust to the inclusion of 2008 crisis as Table 4.7.4 shows.

present in the top median LETP instruments by liquidity. Highly leveraged ETP portfolios are negative beta assets with positive expected returns. These LETP portfolios do have a potential diversification benefit. In contrast, low volatility asset classes show neither substantial slippage nor negative exposure to the broad underlying ETP market.

4.5.4 Leveraged ETPs as a Diversification Instrument

Empirical findings show that LETPs should be shorted on average. This implies that LETPs do have some pitfalls for holding periods longer than a day. In this regard the financial press alerts their readers about LETPs. For instance, *The Financial Times:* "Risk betting on short and leveraged ETFs", 2 November 2010, warns retail investors about the risks associated with investing in LETPs. Similarly, *The Wall Street Journal*, "Beware Leveraged ETFs", 11 May 2012, highlights the misunderstanding of retail investors regarding LETPs. In the same manner, *The Financial Times:* "Worries over exotic exchange traded funds deepen", 14 February 2018, raises questions about the proliferation of LETPs and their implications for market integrity.

Despite several articles warning about the risk associated with LETPs, this section shows that LETPs could be used to reduce risk. Constructing LETP portfolios as suggested in this paper and combining them with a same asset class ETP market portfolio achieves diversification benefits. Especially in high volatility asset classes such as developed and emerging equity markets, LETP portfolios show market neutrality or even negative beta characteristics. Therefore, combining them with the market portfolio leads to a more stable performance due to the presence of assets that co-move negatively. This negative correlation argument is in line with the discussion of Asness et al. (2013) regarding the combination of value and momentum.

To address this topic, I build three portfolio types. The first type is a a broad equally weighted market portfolio composed of all ETPs of a specific asset class. The second type is an unconditional or conditional LETP portfolio sorted by either β, σ, $\sigma\rho_1$ or ρ_1. For conditional portfolios, I only consider high terciles.[23] The third portfolio type is a 50%-50% combination of the first and second type at the time of portfolio construction. For instance, 50% of capital is allocated to the ETP portfolio and the remaining 50% is allocated to the high tercile LETP portfolio sorted by σ. I refer to this combination as a 50%-50% allocation. The following analysis covers two asset classes: equity developed and equity emerging markets.[24]

Furthermore, I report a graphical analysis in which the three sets of portfolios are plotted as a function of their ex-post realized volatility and their ex-post realized CAPM-β estimated over the full sample period. I report some additional benchmark lines in the figure. Two vertical lines that match ex-post realized CAPM-β of 1 and 0.5. Then, I plot two horizontal lines. The first horizontal line is at the realized volatility level of the ETP market portfolio. The second horizontal line is at the volatility level (σ_p) resulting from a combination of the market portfolio realized variance (σ^2_{ETP}) and the cross-sectional average realized variance (σ^2_{LETP}) of all LETP portfolios. Assuming a zero correlation and a

[23] LETP portfolios are constructed as delineated in Section 4.4.

[24] Commodity markets show a lower diversification benefit than equity markets.

50% allocation ($w_{ETP} = 50\%$), σ_p is given by,

$$\sigma_p = \left(w_{ETP}^2 \sigma_{ETP}^2 + w_{LETP}^2 \sigma_{LETP}^2\right)^{1/2} \tag{4.2}$$

If the out of sample back-tested 50%-50% allocation of LETP and ETP portfolios resides in the south west panel of the figure, it means that the 50%-50% allocation has an additional diversification benefit deriving from negative correlation. Further, I report the Sharpe ratio range of the different strategies in the figure legend.

4.5.4.1 Equity Developed

To begin with equity developed markets, LETP portfolios exhibit low beta and low volatility relative to the same asset class market portfolio. Panel A of Figure 4.10 shows the pattern in the data. The resulting 50%-50% allocation of LETP portfolios and market portfolios has a realized volatility that is substantially lower than the market portfolio and an ex-post CAPM-β that tends to be below 0.5. Despite the lower risk metrics of the 50%-50% allocations, their annualized Sharpe ratios range between 1.39 and 1.65, while the market portfolio has a Sharpe ratio of 0.89. Panel A of Table 4.9 presents the results of the distribution conditional moments for the double and triple LETP sample and associated portfolios.

Splitting the LETP sample in double and triple leveraged instruments reveals that the diversification effect is clearly stronger in highly leveraged instruments. For instance for the triple LETPs, Panel C of Figure 4.10 shows that the 50%-50% allocations reside in the south west part of the figure. This positioning of the portfolios implies that there is diversification benefit deriving from negative correlation. The opposite co-movement of LETP and market portfolios arises from the rise in volatility and the simultaneous draw-downs of the cash market. Hence, a 50%-50% allocation leads to have low risk metrics and stable asset allocation. As a result, 50%-50% allocation annualized Sharpe ratios range between 1.53 and 1.89, while the market portfolio Sharpe ratio is 0.78 over the same time period. Panel C of Table 4.9 presents the results of the distribution conditional moments.

4.5.4.2 Equity Emerging

Equity emerging cash markets show a relatively flat performance over the post-financial crisis period. It is natural to ask whether a 50%-50% allocation would have led to a more stable performance. Figure 4.11 presents the pattern in the data for equity emerging markets. Also in emerging markets there is a substantial diversification benefit deriving from combining LETP portfolios and ETP market portfolio. Panel A of Figure 4.11 depicts the 50%-50% allocations in the south west part of the plot. The panel shows the results for pooled LETPs with double and triple leverage multipliers. Thanks to the substantial risk reduction of the 50%-50% allocation, the annualized Sharpe ratios of these strategies range between 0.86 and 0.93, whereas the market portfolio yields only 0.32.

Panels B and C of Figure 4.11 show the results when splitting the sample in double and triple leveraged instruments, respectively. Highly leveraged instruments reside consistently in the south west part of the plot. This implies a strong diversification benefit of these combinations deriving from the negative correlation. Thanks to the improvement in risk characteristics with respect to the market portfolio, 50%-50% allocations lead to Sharpe ratios ranging between 0.71 and 1.22, in the triple LETP sub-sample. On the other hand, the market portfolio in emerging markets has a Sharpe ratio of 0.11, over the same time period, as Table 4.10 shows.

In short, combining LETP portfolios and a broad market index can lead to diversification advantages and stable asset allocation. LETP portfolios may be used as zero-cost hedging assets.

4.6 Conclusion

LETP issuers, regulators, practitioners and academics have recognized the pitfall of LETPs over holding periods greater than one day and in volatile environments.

In this paper, I investigate empirically LETP slippage across five different asset classes: equity developed, equity emerging, commodity, fixed income and currency. High volatility asset classes exhibit larger slippage than low volatility asset classes. This pattern confirms at the macro level that LETPs do underperform the underlying ETP market in volatile environments. Analyzing the cross-sectional properties of LETP slippage within each asset class reveals that LETP slippage is more pronounced in instruments with previous year high realized volatility and high market beta. Generally, sorting measures that include some component of realized volatility have consistent selection ability. Intuitively, volatility clusters and is persistent across time and securities. The slippage is larger if LETPs are aggregated across asset classes and among the most liquid LETP instruments.

Notably, LETP portfolios are zero or negatively correlated with the same asset class ETP market portfolio. As a result, combining LETP portfolios and a broad market index can have a diversification benefit in terms of standard deviation and ex-post market beta exposure. The resulting asset allocation achieves a substantially larger Sharpe ratio than a mere long position in the ETP market. Despite the several hidden drawbacks highlighted by the financial press and regulator, LETP slippage could be used as a low cost hedging instrument.

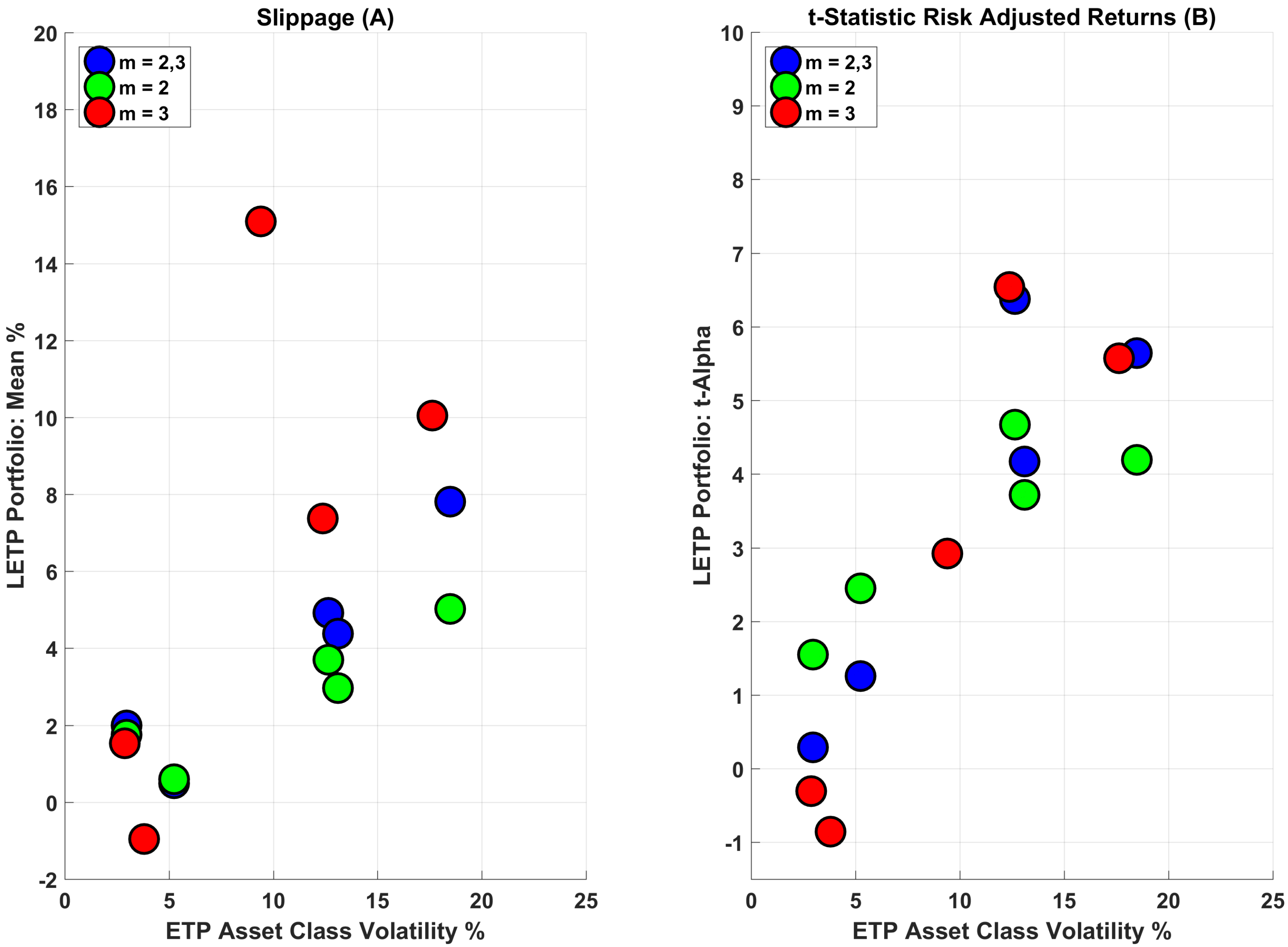

Figure 4.1
Slippage and Volatility Across Asset Classes

This figure shows annualized average return (Mean %) and t-statistic of CAPM risk-adjusted returns (t-Alpha) of LETP portfolio strategies across asset classes. These two portfolio performance measures are plotted as a function of the realized volatility of the same asset class ETP market portfolio over the full sample period. t-Alpha is computed by time series regression of LETP portfolio returns on ETP market portfolio returns. The asset classes considered are: equity developed, equity emerging, commodity, fixed income and currency markets. At the beginning of each month and for each asset class, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This portfolio is denoted as the unconditional LETP portfolio for which Mean % and t-Alpha are computed. Within each asset class, the equally weighted market portfolio is comprised of all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Results are presented by using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Results are presented also by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Additional information is provided in Table 4.1.

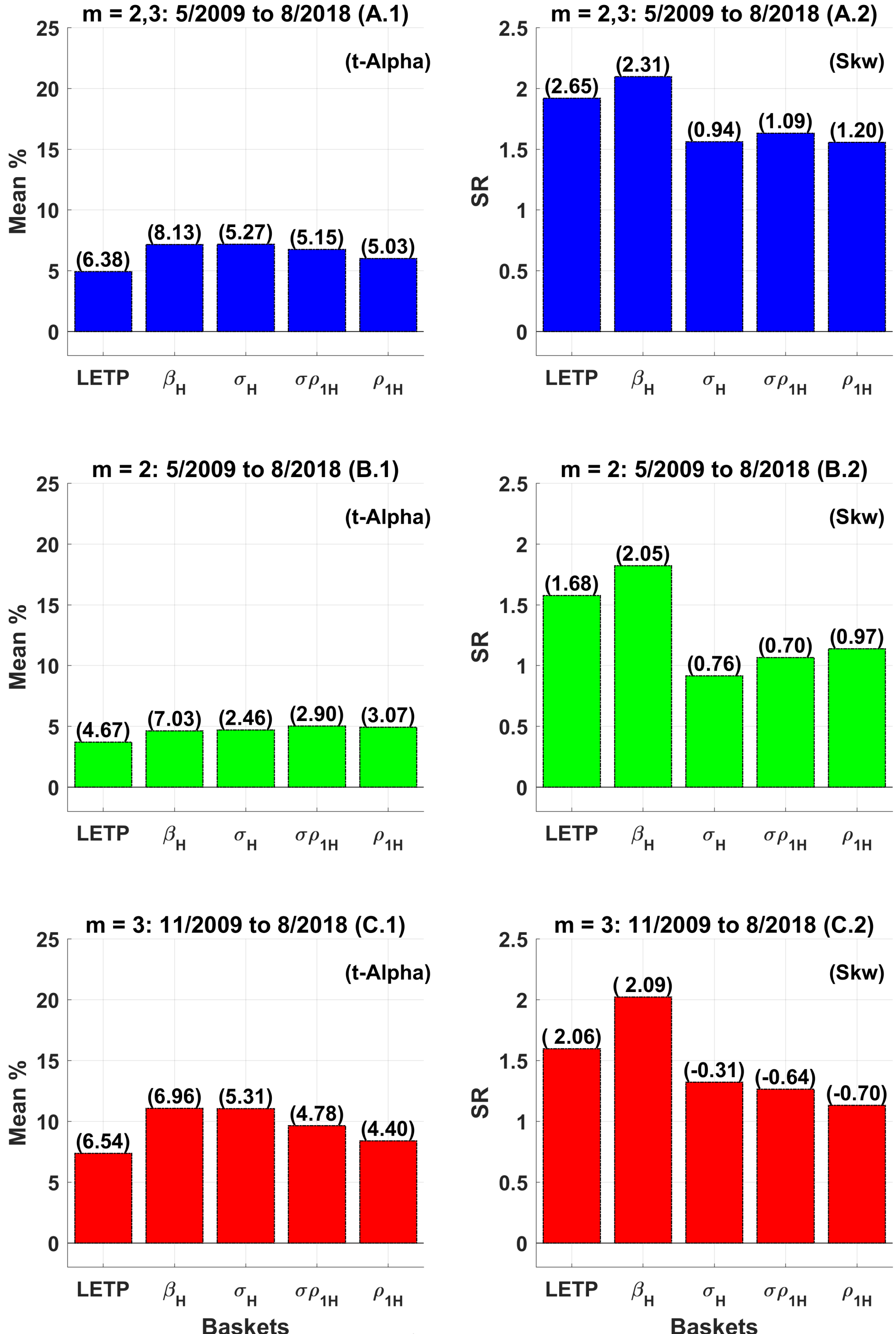

Figure 4.2

Cross-Section of LETP Slippage: Equity Developed

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.2.

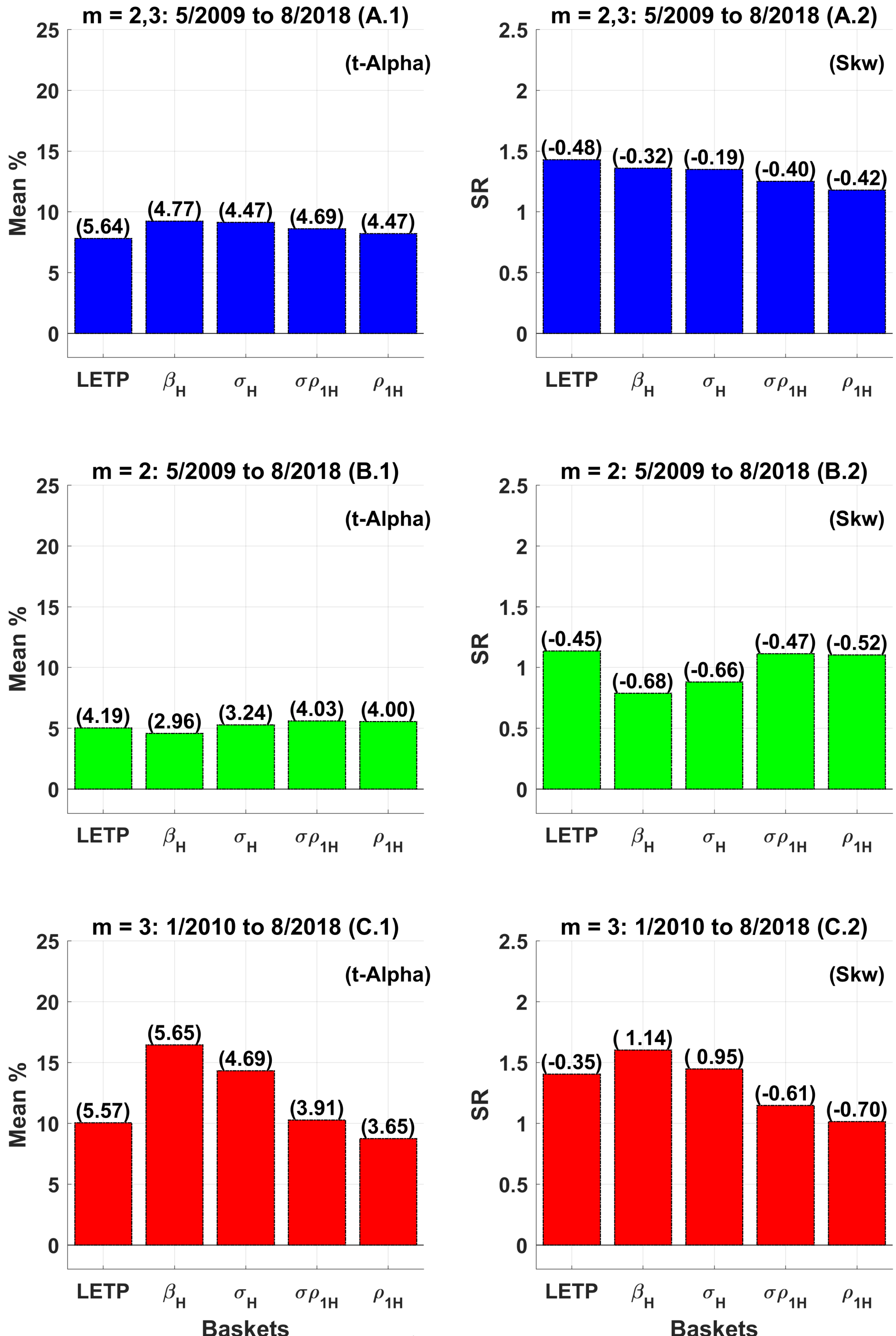

Figure 4.3

Cross-Section of LETP Slippage: Equity Emerging

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.3.

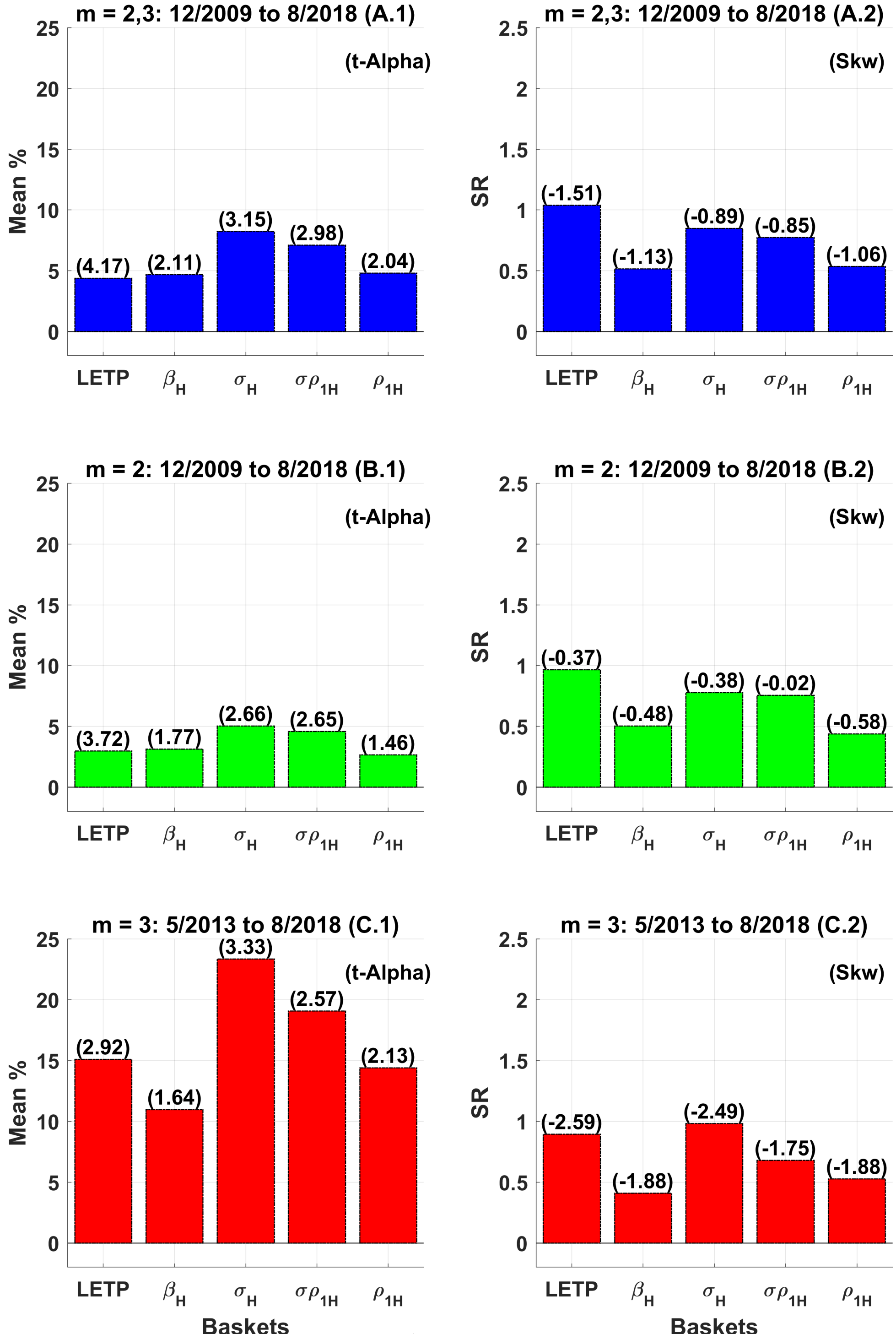

Figure 4.4

Cross-Section of LETP Slippage: Commodity

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.4.

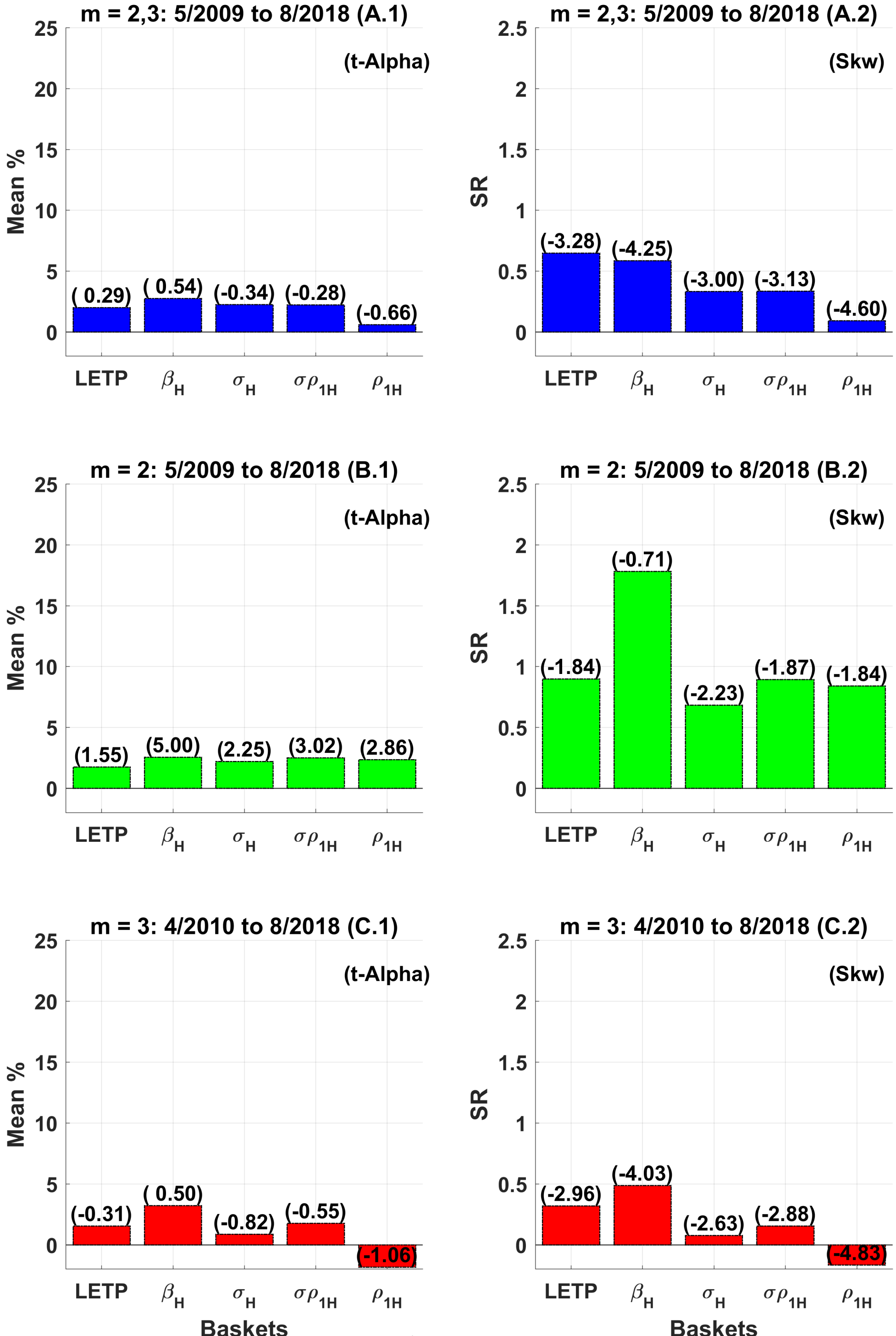

Figure 4.5

Cross-Section of LETP Slippage: Fixed Income

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.5.

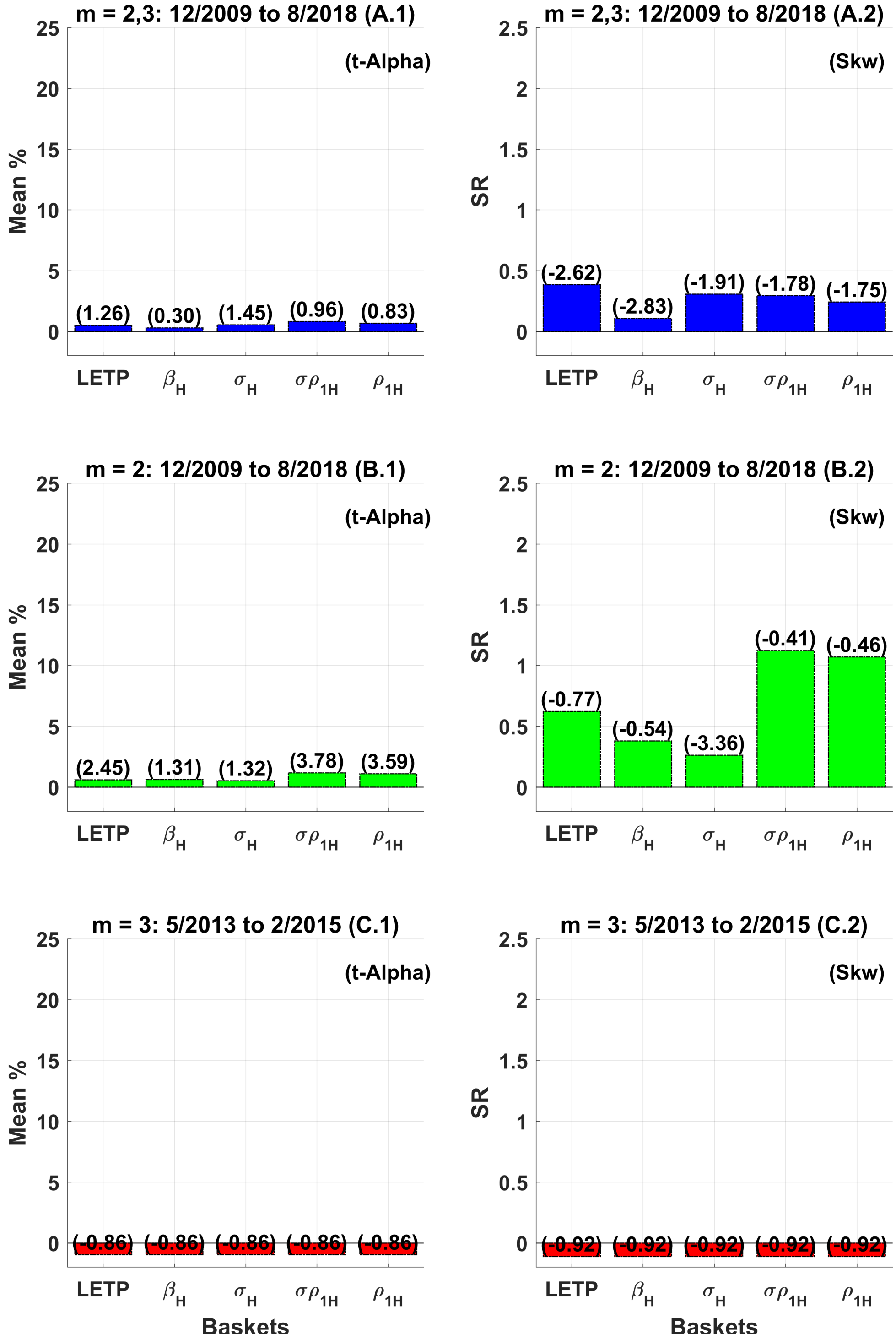

Figure 4.6

Cross-Section of LETP Slippage: Currency

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.6.

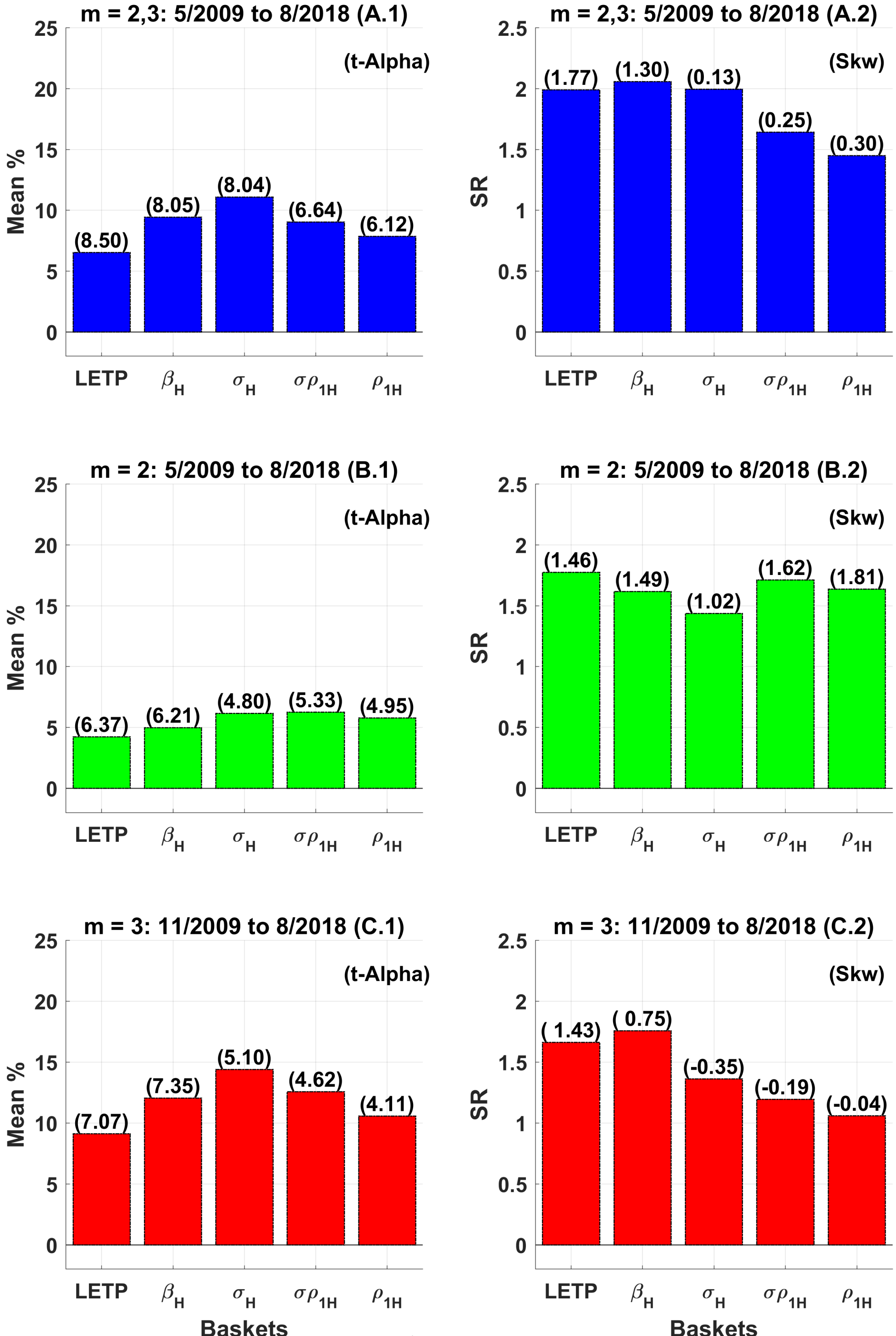

Figure 4.7

Cross-Section of LETP Slippage: High Volatility Asset Classes

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.7.

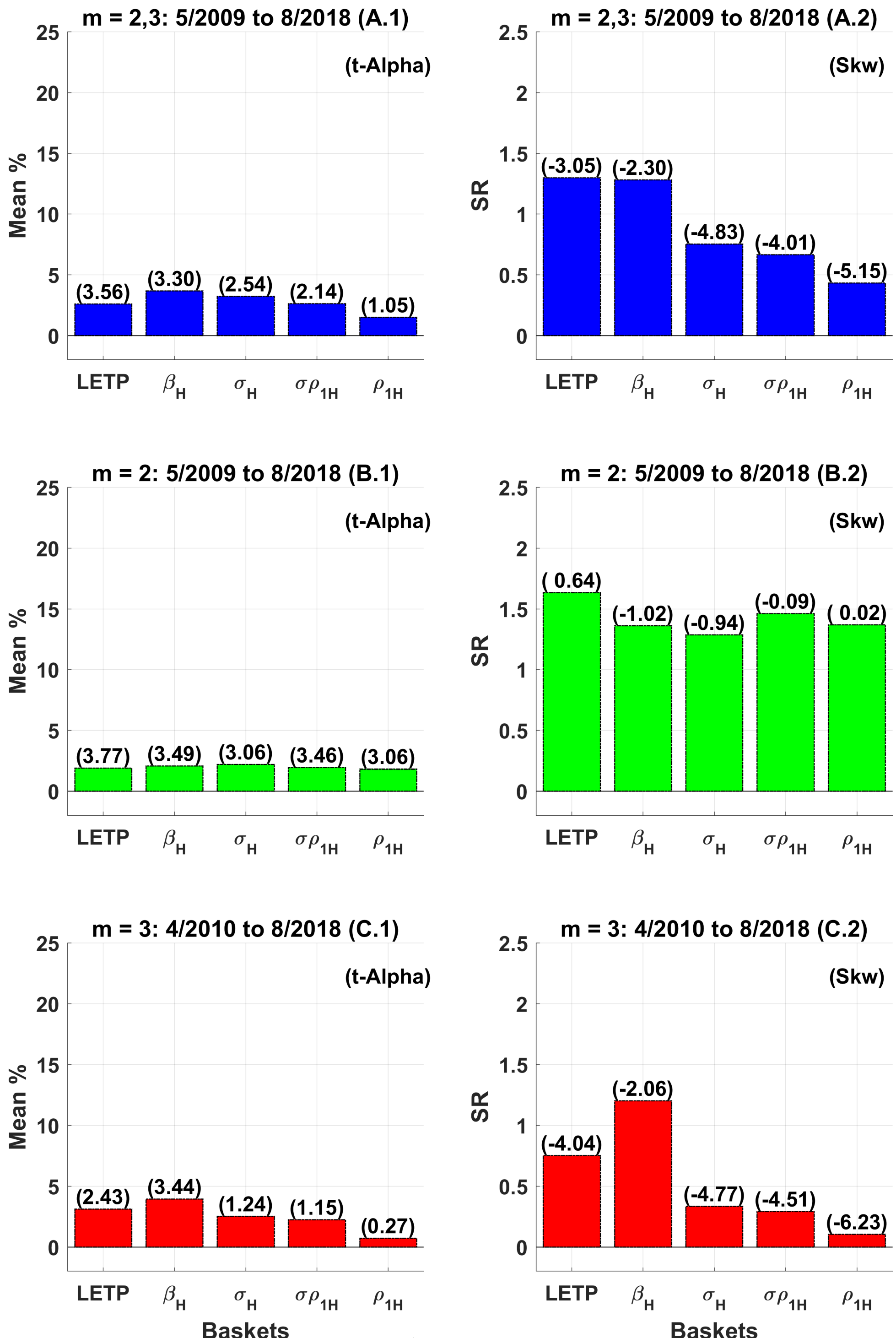

Figure 4.8

Cross-Section of LETP Slippage: Low Volatility Asset Classes

This figure shows annualized average return (Mean %) and Sharpe ratio (SR) of LETP portfolio strategies. The figure also reports t-statistic of CAPM risk-adjusted returns (t-Alpha) and the skewness of the strategies (Skw). At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section (labeled LETP in the figure). LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures. Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. The ranking measures estimated with daily returns over the year preceding portfolio construction are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). For example, σ_H is the high tercile sorted by σ. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel. See Table 4.8.

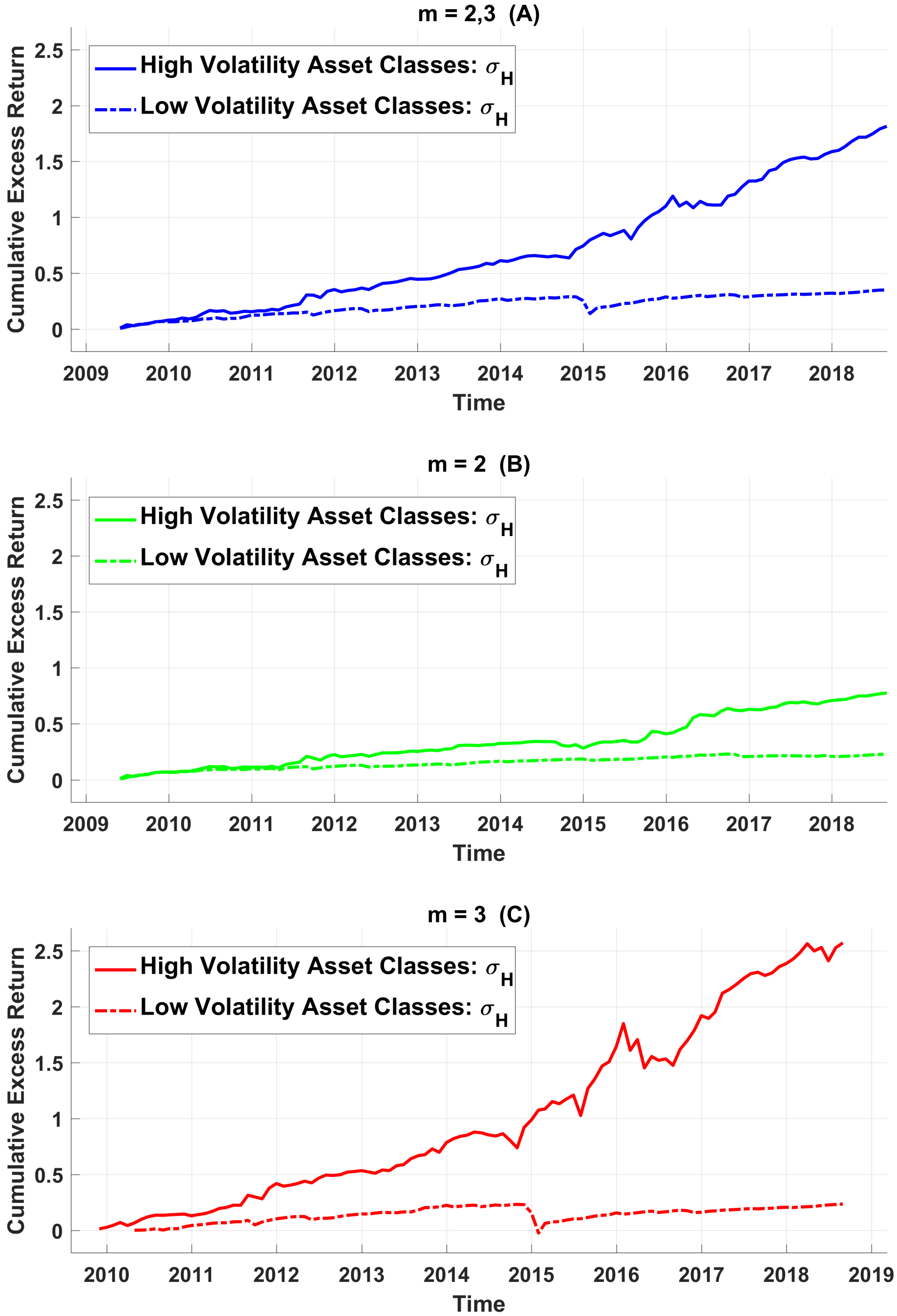

Figure 4.9

LETP Slippage in High and Low Volatility Asset Classes

This figure shows cumulative excess returns of high and low volatility asset classes LETP portfolios. High volatility asset classes include equity developed, equity emerging and commodity markets. Low volatility asset classes include fixed income and currency markets. For each high and low volatility asset classes, the figure reports high (H) tercile LETP portfolios sorted by σ (labeled σ_H). See Table 4.7 and 4.8 for additional information on portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel.

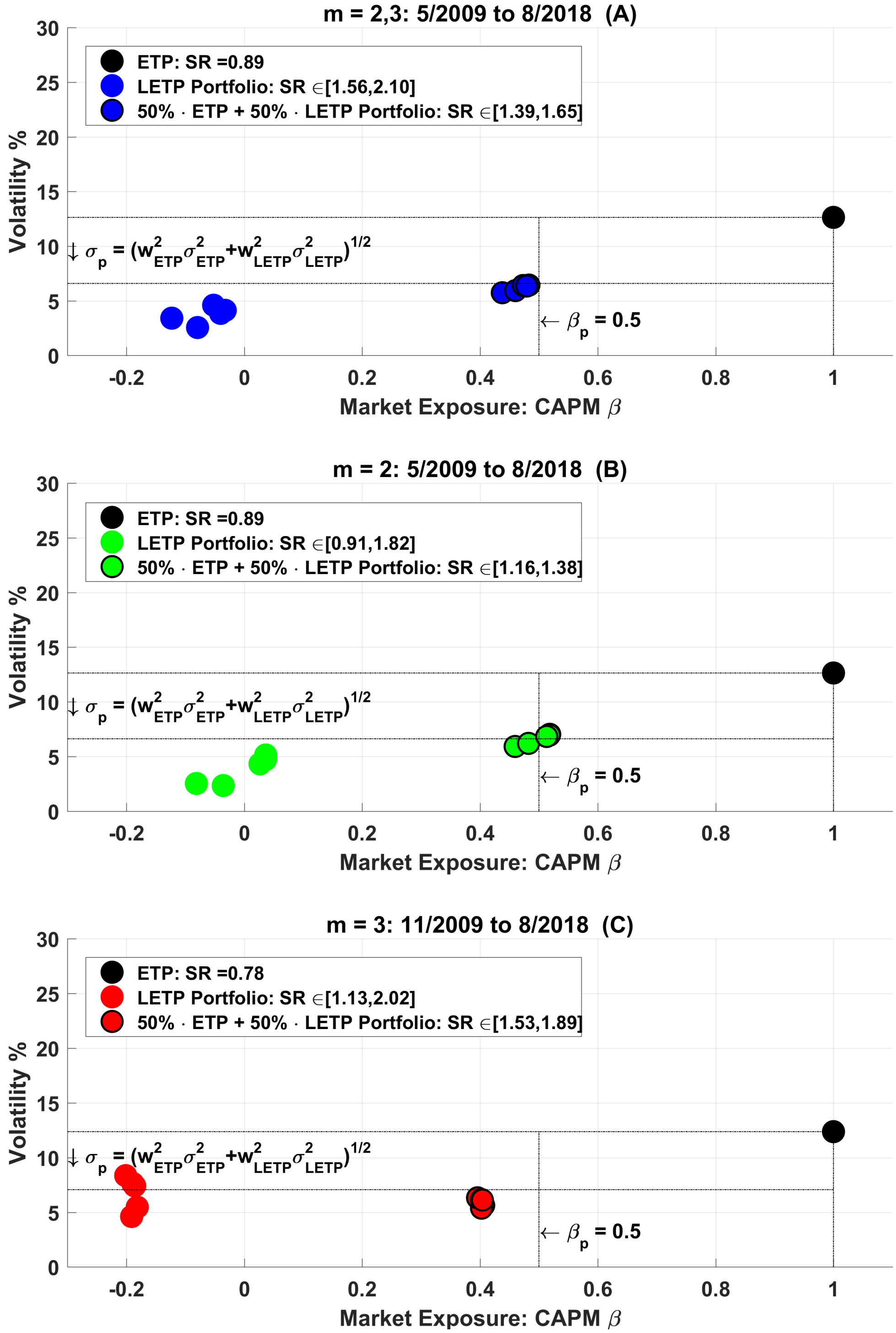

Figure 4.10

LETPs as a Diversification Instrument: Equity Developed

This figure reports risk profiles of LETP and ETP portfolio strategies. These portfolio strategies are plotted as a function of their ex-post realized volatility (y-axis) and their ex-post realized CAPM-β (x-axis) estimated over the full sample period. For each portfolio type, the legend reports its annualized Sharpe ratio (SR) range. The figure reports three portfolio types. The first type is a broad equally weighted market portfolio composed of all ETPs of a specific asset class (labeled ETP). The second type is an unconditional or conditional LETP portfolio sorted by either β, σ, $\sigma\rho_1$ or ρ_1 (labeled LETP Portfolio). For conditional portfolios, only high terciles are considered. The third portfolio type is a 50%-50% combination of the first and second type at portfolio construction. For instance, 50% of capital is allocated to the ETP portfolio and the remaining 50% is allocated to the high tercile LETP portfolio sorted by σ. See Table 4.9 for additional information on portfolio construction. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel.

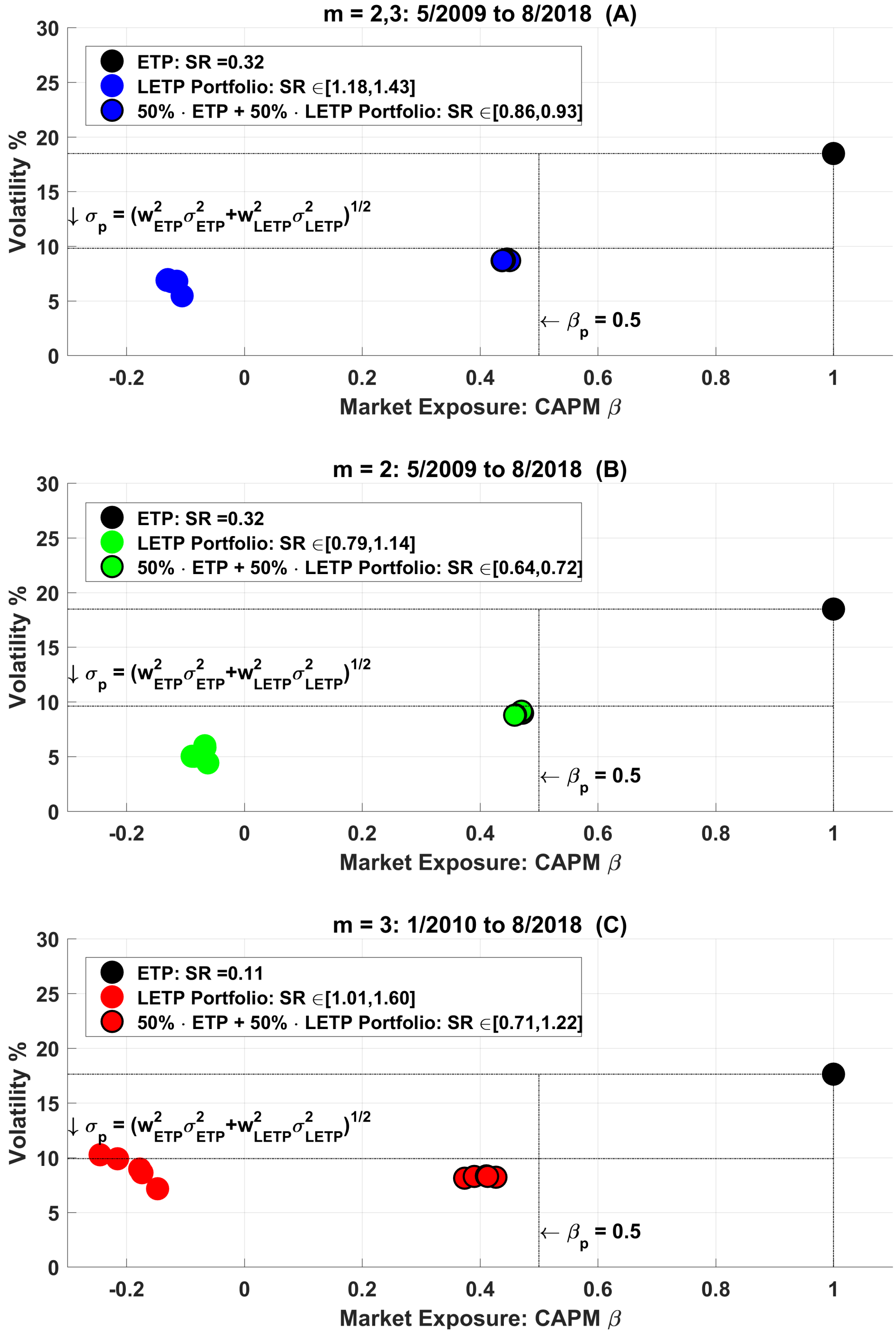

Figure 4.11

LETPs as a Diversification Instrument: Equity Emerging

This figure reports risk profiles of LETP and ETP portfolio strategies. These portfolio strategies are plotted as a function of their ex-post realized volatility (y-axis) and their ex-post realized CAPM-β (x-axis) estimated over the full sample period. For each portfolio type, the legend reports its annualized Sharpe ratio (SR) range. The figure reports three portfolio types. The first type is a broad equally weighted market portfolio composed of all ETPs of a specific asset class (labeled ETP). The second type is an unconditional or conditional LETP portfolio sorted by either β, σ, $\sigma\rho_1$ or ρ_1 (labeled LETP Portfolio). For conditional portfolios, only high terciles are considered. The third portfolio type is a 50%-50% combination of the first and second type at portfolio construction. For instance, 50% of capital is allocated to the ETP portfolio and the remaining 50% is allocated to the high tercile LETP portfolio sorted by σ. See Table 4.10 for additional information on portfolio construction. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel.

Table 4.1
Slippage and Volatility Across Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies across asset classes. The sample period is shown in each panel. At the beginning of each month and for each asset class, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. In the same vane, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the same asset class ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	Eq. Developed		**Eq. Emerging**		**Commodity**		**Fixed Income**		**Currency**	
	ETP	LETP	ETP	LETP	ETP	LETP	ETP	LETP	ETP	LETP
A) m = 2,3;	*5/2009 to 8/2018*		*5/2009 to 8/2018*		*12/2009 to 8/2018*		*5/2009 to 8/2018*		*12/2009 to 8/2018*	
μ	11.22	4.92	5.99	7.81	-3.41	4.38	3.35	1.99	-1.38	0.49
SR	0.89	1.92	0.32	1.43	-0.26	1.04	1.13	0.65	-0.26	0.39
Std	12.64	2.56	18.48	5.47	13.10	4.22	2.96	3.08	5.24	1.28
Skw	-0.31	2.65	-0.02	-0.48	-0.88	-1.51	-0.28	-3.28	-0.21	-2.62
α		5.81		8.44		4.34		0.48		0.47
t-α		6.38		5.64		4.17		0.29		1.26
B) m = 2;	*5/2009 to 8/2018*		*5/2009 to 8/2018*		*12/2009 to 8/2018*		*5/2009 to 8/2018*		*12/2009 to 8/2018*	
μ	11.22	3.70	5.99	5.02	-3.41	2.97	3.35	1.75	-1.38	0.60
SR	0.89	1.58	0.32	1.14	-0.26	0.97	1.13	0.90	-0.26	0.62
Std	12.64	2.35	18.48	4.42	13.10	3.07	2.96	1.95	5.24	0.96
Skw	-0.31	1.68	-0.02	-0.45	-0.88	-0.37	-0.28	-1.84	-0.21	-0.77
α		4.10		5.39		2.88		1.30		0.62
t-α		4.67		4.19		3.72		1.55		2.45
C) m = 3;	*11/2009 to 8/2018*		*1/2010 to 8/2018*		*5/2013 to 8/2018*		*4/2010 to 8/2018*		*5/2013 to 2/2015*	
μ	9.66	7.37	1.85	10.05	-7.22	15.09	2.92	1.53	-5.16	-0.96
SR	0.78	1.60	0.11	1.40	-0.77	0.89	1.02	0.32	-1.36	-0.11
Std	12.37	4.62	17.63	7.16	9.40	16.89	2.88	4.80	3.80	8.50
Skw	-0.36	2.06	-0.29	-0.35	0.18	-2.59	-0.37	-2.96	-0.03	-0.92
α		9.22		10.32		18.00		-0.75		-5.11
t-α		6.54		5.57		2.92		-0.31		-0.86

Table 4.2
Cross-Section of LETP Slippage: Equity Developed

This table reports portfolio performance metrics for LETP and ETP strategies in equity developed markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_{H}	β_{L}	σ_{H}	σ_{L}	$\sigma\rho_{1\mathrm{H}}$	$\sigma\rho_{1\mathrm{L}}$	$\rho_{1\mathrm{H}}$	$\rho_{1\mathrm{L}}$
A) m = 2,3; 5/2009 to 8/2018										
μ	11.22	4.92	7.16	3.58	7.19	3.26	6.74	3.93	6.01	4.08
SR	0.89	1.92	2.10	0.97	1.56	1.70	1.63	1.43	1.56	1.48
Std	12.64	2.56	3.42	3.67	4.60	1.91	4.13	2.76	3.86	2.75
Skw	-0.31	2.65	2.31	0.45	0.94	1.57	1.09	0.58	1.20	0.63
α		5.81	8.55	3.73	7.77	4.16	7.11	5.13	6.46	5.19
t-α		6.38	8.13	3.08	5.27	6.15	5.15	6.08	5.03	6.58
β		-0.08	-0.12	-0.01	-0.05	-0.08	-0.03	-0.11	-0.04	-0.10
t-β		-2.74	-3.88	-0.34	-1.13	-3.67	-0.71	-3.55	-0.95	-3.46
B) m = 2; 5/2009 to 8/2018										
μ	11.22	3.70	4.63	3.76	4.71	3.01	5.04	3.03	4.94	3.14
SR	0.89	1.58	1.82	0.76	0.91	1.82	1.07	1.30	1.14	1.34
Std	12.64	2.35	2.54	4.92	5.15	1.66	4.72	2.33	4.33	2.35
Skw	-0.31	1.68	2.05	0.98	0.76	1.24	0.70	0.38	0.97	0.58
α		4.10	5.54	3.27	4.30	3.63	4.64	3.85	4.64	3.88
t-α		4.67	7.03	2.05	2.46	5.77	2.90	5.15	3.07	5.52
β		-0.04	-0.08	0.04	0.04	-0.05	0.04	-0.07	0.03	-0.07
t-β		-1.18	-3.45	0.71	0.57	-2.64	0.58	-2.91	0.47	-2.90
C) m = 3; 11/2009 to 8/2018										
μ	9.66	7.37	11.07	4.53	11.05	4.84	9.65	6.18	8.40	6.33
SR	0.78	1.60	2.02	0.68	1.32	1.29	1.26	1.21	1.13	1.24
Std	12.37	4.62	5.47	6.68	8.35	3.75	7.64	5.09	7.42	5.10
Skw	-0.36	2.06	2.09	-1.51	-0.31	1.45	-0.64	1.24	-0.70	1.23
α		9.22	12.82	6.06	13.00	6.65	11.48	8.13	10.20	8.34
t-α		6.54	6.96	3.01	5.31	5.73	4.78	5.31	4.40	5.90
β		-0.19	-0.18	-0.16	-0.20	-0.19	-0.19	-0.20	-0.19	-0.21
t-β		-4.52	-3.12	-4.34	-3.97	-4.80	-3.88	-3.82	-3.80	-4.01

Table 4.3

Cross-Section of LETP Slippage: Equity Emerging

This table reports portfolio performance metrics for LETP and ETP strategies in equity emerging markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 5/2009 to 8/2018										
μ	5.99	7.81	9.24	7.18	9.13	6.52	8.61	5.46	8.19	5.77
SR	0.32	1.43	1.36	1.24	1.35	1.20	1.25	0.99	1.18	1.05
Std	18.48	5.47	6.80	5.78	6.76	5.43	6.88	5.51	6.95	5.49
Skw	-0.02	-0.48	-0.32	-0.27	-0.19	0.58	-0.40	-1.06	-0.42	-1.19
α		8.44	9.92	7.78	9.87	7.10	9.40	5.81	8.97	6.15
t-α		5.64	4.77	5.30	4.47	4.58	4.69	3.67	4.47	4.02
β		-0.11	-0.11	-0.10	-0.12	-0.10	-0.13	-0.06	-0.13	-0.06
t-β		-2.20	-2.00	-2.07	-2.24	-2.28	-2.46	-1.18	-2.46	-1.23
B) m = 2; 5/2009 to 8/2018										
μ	5.99	5.02	4.59	5.13	5.28	5.41	5.60	3.33	5.55	4.26
SR	0.32	1.14	0.79	1.12	0.88	1.24	1.11	0.70	1.10	0.89
Std	18.48	4.42	5.83	4.57	5.99	4.38	5.03	4.76	5.03	4.78
Skw	-0.02	-0.45	-0.68	0.28	-0.66	0.98	-0.47	-0.83	-0.52	-1.02
α		5.39	4.99	5.59	5.68	5.90	6.11	3.54	6.08	4.48
t-α		4.19	2.96	4.22	3.24	4.93	4.03	2.36	4.00	3.03
β		-0.06	-0.07	-0.08	-0.07	-0.08	-0.09	-0.03	-0.09	-0.04
t-β		-1.59	-1.45	-2.16	-1.40	-2.61	-2.19	-0.82	-2.29	-0.85
C) m = 3; 1/2010 to 8/2018										
μ	1.85	10.05	16.45	9.67	14.32	6.46	10.27	10.55	8.74	10.97
SR	0.11	1.40	1.60	1.18	1.45	0.93	1.15	1.29	1.01	1.37
Std	17.63	7.16	10.26	8.20	9.90	6.97	8.96	8.21	8.62	8.00
Skw	-0.29	-0.35	1.14	-0.40	0.95	-0.33	-0.61	0.46	-0.70	0.43
α		10.32	16.91	9.83	14.72	6.67	10.60	10.82	9.06	11.22
t-α		5.57	5.65	4.53	4.69	3.74	3.91	4.88	3.65	4.95
β		-0.15	-0.24	-0.08	-0.22	-0.12	-0.18	-0.15	-0.17	-0.14
t-β		-2.12	-3.40	-0.89	-2.57	-1.76	-2.43	-1.92	-2.48	-1.85

Table 4.4

Cross-Section of LETP Slippage: Commodity

This table reports portfolio performance metrics for LETP and ETP strategies in commodity markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_{H}	β_{L}	σ_{H}	σ_{L}	$\sigma\rho_{1\mathrm{H}}$	$\sigma\rho_{1\mathrm{L}}$	$\rho_{1\mathrm{H}}$	$\rho_{1\mathrm{L}}$
A) m = 2,3; 12/2009 to 8/2018										
μ	-3.41	4.38	4.67	2.48	8.24	0.93	7.10	5.02	4.81	6.25
SR	-0.26	1.04	0.51	0.75	0.85	0.29	0.77	1.24	0.54	1.53
Std	13.10	4.22	9.08	3.30	9.71	3.16	9.19	4.04	8.98	4.08
Skw	-0.88	-1.51	-1.13	1.75	-0.89	-0.88	-0.85	-0.73	-1.06	-0.15
α		4.34	4.43	2.53	8.06	0.90	6.97	4.88	4.87	6.13
t-α		4.17	2.11	1.98	3.15	1.21	2.98	3.76	2.04	4.41
β		-0.01	-0.07	0.02	-0.05	-0.01	-0.04	-0.04	0.02	-0.04
t-β		-0.25	-0.83	0.51	-0.60	-0.45	-0.45	-1.29	0.20	-1.22
B) m = 2; 12/2009 to 8/2018										
μ	-3.41	2.97	3.13	1.41	5.04	0.69	4.58	5.07	2.64	5.39
SR	-0.26	0.97	0.50	0.42	0.78	0.24	0.76	0.96	0.44	0.95
Std	13.10	3.07	6.22	3.38	6.49	2.85	6.06	5.31	6.04	5.69
Skw	-0.88	-0.37	-0.48	0.12	-0.38	-1.32	-0.02	3.19	-0.58	2.19
α		2.88	2.80	1.42	4.77	0.70	4.37	4.86	2.59	5.20
t-α		3.72	1.77	1.40	2.66	0.88	2.65	2.71	1.46	3.32
β		-0.03	-0.10	0.00	-0.08	0.00	-0.06	-0.06	-0.02	-0.06
t-β		-0.69	-1.40	0.13	-1.04	0.11	-0.87	-2.06	-0.24	-1.98
C) m = 3; 5/2013 to 8/2018										
μ	-7.22	15.09	10.96	14.44	23.35	3.79	19.08	8.58	14.40	10.57
SR	-0.77	0.89	0.41	0.68	0.98	0.16	0.68	0.42	0.53	0.50
Std	9.40	16.89	26.72	21.16	23.79	24.33	28.12	20.36	27.30	21.27
Skw	0.18	-2.59	-1.88	-1.58	-2.49	-1.24	-1.75	-1.69	-1.88	-1.37
α		18.00	15.69	15.26	27.50	5.50	24.84	8.53	20.83	10.24
t-α		2.92	1.64	1.48	3.33	0.62	2.57	0.93	2.13	1.11
β		0.40	0.65	0.11	0.57	0.24	0.80	-0.01	0.89	-0.04
t-β		1.19	1.25	0.30	1.28	0.48	1.43	-0.02	1.63	-0.14

Table 4.5

Cross-Section of LETP Slippage: Fixed Income

This table reports portfolio performance metrics for LETP and ETP strategies in fixed income markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 5/2009 to 8/2018										
μ	3.35	1.99	2.73	0.80	2.24	1.82	2.21	2.15	0.60	2.19
SR	1.13	0.65	0.59	0.17	0.33	1.17	0.33	1.04	0.09	0.80
Std	2.96	3.08	4.66	4.58	6.75	1.56	6.60	2.07	6.53	2.73
Skw	-0.28	-3.28	-4.25	-6.76	-3.00	-3.74	-3.13	-0.92	-4.60	0.93
α		0.48	1.16	-0.75	-1.14	1.49	-1.00	1.69	-2.58	1.22
t-α		0.29	0.54	-0.29	-0.34	1.88	-0.28	2.30	-0.66	1.42
β		0.45	0.47	0.46	1.01	0.10	0.96	0.14	0.95	0.29
t-β		1.93	1.72	1.31	2.09	0.97	2.00	1.29	1.81	2.05
B) m = 2; 5/2009 to 8/2018										
μ	3.35	1.75	2.55	0.89	2.19	1.10	2.50	0.91	2.35	0.94
SR	1.13	0.90	1.78	0.24	0.68	0.41	0.89	0.32	0.84	0.33
Std	2.96	1.95	1.43	3.71	3.21	2.67	2.80	2.87	2.79	2.87
Skw	-0.28	-1.84	-0.71	-3.14	-2.23	-6.97	-1.87	-5.63	-1.84	-5.68
α		1.30	2.52	-0.13	1.87	0.41	2.20	0.22	2.07	0.14
t-α		1.55	5.00	-0.08	2.25	0.29	3.02	0.16	2.86	0.10
β		0.14	0.01	0.30	0.09	0.21	0.09	0.21	0.08	0.24
t-β		1.38	0.19	1.40	1.13	1.08	1.06	1.12	1.03	1.28
C) m = 3; 4/2010 to 8/2018										
μ	2.92	1.53	3.20	0.81	0.87	0.85	1.76	2.94	-1.85	3.47
SR	1.02	0.32	0.49	0.17	0.08	0.27	0.15	1.46	-0.17	0.75
Std	2.88	4.80	6.60	4.82	11.46	3.14	11.36	2.02	11.02	4.61
Skw	-0.37	-2.96	-4.03	-7.05	-2.63	-8.38	-2.88	4.63	-4.83	2.86
α		-0.75	1.57	-0.78	-4.52	0.01	-3.25	2.77	-6.80	2.57
t-α		-0.31	0.50	-0.29	-0.82	0.01	-0.55	3.91	-1.06	1.88
β		0.78	0.56	0.54	1.84	0.29	1.71	0.06	1.69	0.31
t-β		2.04	1.27	1.32	2.17	1.12	1.99	1.03	1.80	1.63

Table 4.6

Cross-Section of LETP Slippage: Currency

This table reports portfolio performance metrics for LETP and ETP strategies in currency markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 12/2009 to 8/2018										
μ	-1.38	0.49	0.30	0.57	0.54	0.79	0.81	0.33	0.66	-0.59
SR	-0.26	0.39	0.11	0.35	0.31	0.36	0.29	0.20	0.24	-0.13
Std	5.24	1.28	2.81	1.64	1.76	2.18	2.75	1.63	2.74	4.65
Skw	-0.21	-2.62	-2.83	-3.03	-1.91	4.67	-1.78	-1.73	-1.75	-3.87
α		0.47	0.22	0.64	0.58	0.70	0.73	0.35	0.60	-0.48
t-α		1.26	0.30	1.49	1.45	1.38	0.96	0.81	0.83	-0.42
β		-0.01	-0.06	0.05	0.03	-0.07	-0.06	0.01	-0.05	0.08
t-β		-0.54	-0.97	1.29	0.60	-1.18	-1.03	0.18	-0.91	1.09
B) m = 2; 12/2009 to 8/2018										
μ	-1.38	0.60	0.62	0.63	0.51	0.63	1.18	0.67	1.10	0.66
SR	-0.26	0.62	0.38	0.44	0.26	0.58	1.12	0.46	1.07	0.45
Std	5.24	0.96	1.62	1.45	1.96	1.07	1.05	1.47	1.03	1.47
Skw	-0.21	-0.77	-0.54	-2.76	-3.36	-0.99	-0.41	-0.72	-0.46	-0.70
α		0.62	0.59	0.65	0.59	0.60	1.18	0.63	1.10	0.62
t-α		2.45	1.31	1.66	1.32	2.07	3.78	1.70	3.59	1.65
β		0.02	-0.02	0.01	0.05	-0.02	-0.00	-0.03	-0.00	-0.03
t-β		0.66	-0.42	0.38	1.03	-0.75	-0.01	-0.71	-0.21	-0.73
C) m = 3; 5/2013 to 2/2015										
μ	-5.16	-0.96	-0.96	-0.96	-0.96	-0.96	-0.96	-0.96	-0.96	-0.96
SR	-1.36	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Std	3.80	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
Skw	-0.03	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92
α		-5.11	-5.11	-5.11	-5.11	-5.11	-5.11	-5.11	-5.11	-5.11
t-α		-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86
β		-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80
t-β		-1.54	-1.54	-1.54	-1.54	-1.54	-1.54	-1.54	-1.54	-1.54

Table 4.7
Cross-Section of LETP Slippage: High Volatility Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies in high volatility asset classes which includes: equity developed, equity emerging and commodity markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. After this, the top 50% most liquid LETPs are selected in the cross-section. The liquidity measure is defined as the LETP average daily volume over three months preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) $m = 2,3$; 5/2009 to 8/2018										
μ	9.55	6.52	9.43	4.61	11.09	3.55	9.04	5.47	7.86	5.55
SR	0.75	1.99	2.06	1.20	2.00	1.46	1.64	1.64	1.45	1.62
Std	12.76	3.28	4.58	3.84	5.56	2.44	5.51	3.34	5.42	3.43
Skw	-0.29	1.77	1.30	-0.55	0.13	2.29	0.25	0.75	0.30	0.82
α		7.63	10.79	5.51	12.51	4.57	10.32	6.57	9.32	6.61
t-α		8.50	8.05	5.24	8.04	7.00	6.64	8.20	6.12	8.00
β		-0.12	-0.14	-0.09	-0.15	-0.11	-0.13	-0.12	-0.15	-0.11
t-β		-3.82	-3.70	-4.44	-3.93	-4.78	-3.41	-3.70	-4.21	-3.36
B) $m = 2$; 5/2009 to 8/2018										
μ	9.55	4.22	4.99	3.97	6.15	2.64	6.26	3.28	5.78	3.42
SR	0.75	1.77	1.62	1.00	1.44	1.54	1.71	1.29	1.64	1.25
Std	12.76	2.38	3.08	3.97	4.28	1.71	3.65	2.55	3.53	2.73
Skw	-0.29	1.46	1.49	3.75	1.02	1.34	1.62	0.15	1.81	0.11
α		4.72	5.77	4.18	6.45	3.29	6.52	4.02	6.10	4.16
t-α		6.37	6.21	3.28	4.80	6.94	5.33	6.10	4.95	6.06
β		-0.05	-0.08	-0.02	-0.03	-0.07	-0.03	-0.08	-0.03	-0.08
t-β		-2.17	-3.13	-0.68	-0.79	-4.20	-0.85	-3.15	-1.06	-2.92
C) $m = 3$; 11/2009 to 8/2018										
μ	7.83	9.12	12.06	6.56	14.41	4.86	12.58	6.16	10.58	6.92
SR	0.63	1.66	1.76	0.80	1.36	1.18	1.20	1.21	1.06	1.32
Std	12.44	5.49	6.85	8.21	10.57	4.13	10.52	5.09	9.99	5.25
Skw	-0.39	1.43	0.75	-0.55	-0.35	1.97	-0.19	0.26	-0.04	0.13
α		10.58	13.45	8.11	15.57	6.39	14.09	7.46	12.16	8.18
t-α		7.07	7.35	3.39	5.10	5.21	4.62	5.22	4.11	6.09
β		-0.19	-0.18	-0.20	-0.15	-0.19	-0.19	-0.17	-0.20	-0.16
t-β		-3.89	-3.28	-3.95	-2.35	-4.46	-2.80	-3.38	-2.89	-3.08

Table 4.8

Cross-Section of LETP Slippage: Low Volatility Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies in low volatility asset classes which includes: fixed income and currency markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. After this, the top 50% most liquid LETPs are selected in the cross-section. The liquidity measure is defined as the LETP average daily volume over three months preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 5/2009 to 8/2018										
μ	2.97	2.59	3.68	1.25	3.22	2.27	2.62	2.21	1.49	2.75
SR	0.97	1.30	1.28	0.37	0.75	2.07	0.67	1.55	0.43	1.27
Std	3.05	1.99	2.87	3.43	4.28	1.10	3.93	1.42	3.45	2.17
Skw	-0.19	-3.05	-2.30	-3.84	-4.83	1.43	-4.01	0.26	-5.15	2.41
α		2.45	3.43	1.40	3.23	2.23	2.56	2.01	1.38	2.79
t-α		3.56	3.30	1.49	2.54	4.56	2.14	3.84	1.05	3.70
β		0.05	0.08	-0.05	-0.00	0.02	0.02	0.07	0.04	-0.01
t-β		0.65	0.71	-0.57	-0.04	0.31	0.17	1.12	0.38	-0.18
B) m = 2; 5/2009 to 8/2018										
μ	2.97	1.91	2.09	1.65	2.21	1.76	1.96	1.71	1.83	1.76
SR	0.97	1.63	1.36	1.25	1.29	1.66	1.46	1.18	1.37	1.13
Std	3.05	1.17	1.53	1.33	1.72	1.06	1.34	1.44	1.33	1.56
Skw	-0.19	0.64	-1.02	0.95	-0.94	1.34	-0.09	0.42	0.02	-0.03
α		1.76	1.88	1.58	1.91	1.62	1.72	1.55	1.55	1.79
t-α		3.77	3.49	3.09	3.06	3.89	3.46	2.95	3.06	3.16
β		0.05	0.07	0.02	0.10	0.05	0.08	0.05	0.09	-0.01
t-β		1.02	1.10	0.43	1.49	1.15	1.74	0.93	1.92	-0.12
C) m = 3; 4/2010 to 8/2018										
μ	2.44	3.11	3.93	1.89	2.52	3.27	2.24	3.43	0.71	4.97
SR	0.83	0.75	1.20	0.26	0.33	1.08	0.29	1.22	0.10	1.18
Std	2.94	4.14	3.27	7.40	7.54	3.02	7.67	2.82	6.85	4.21
Skw	-0.29	-4.04	-2.06	-4.34	-4.77	-1.30	-4.51	-1.99	-6.23	1.63
α		3.09	3.90	2.04	2.64	3.23	2.50	3.20	0.70	5.00
t-α		2.43	3.44	1.00	1.24	3.06	1.15	3.25	0.27	3.49
β		0.01	0.01	-0.06	-0.05	0.02	-0.11	0.09	0.00	-0.01
t-β		0.06	0.10	-0.27	-0.25	0.10	-0.48	0.73	0.01	-0.07

Table 4.9

LETPs as a Diversification Instrument: Equity Developed

This table reports portfolio performance metrics for LETP and ETP strategies in equity developed markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. As a diversification argument, a 50%-50% allocation between either unconditional or high LETP portfolios and same asset class ETP market portfolio is built. Namely, these portfolios are 50% invested in one of the LETP portfolios and 50% invested in ETP market portfolio. For instance, $\sigma_H^{50\%}$ is the portfolio that invests 50% is the high tercile sorted by σ and 50% in ETP market portfolio. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	LETP$^{50\%}$	β_{H}	σ_{H}	$\sigma\rho_{1\mathrm{H}}$	$\rho_{1\mathrm{H}}$	$\beta_{\mathrm{H}}^{50\%}$	$\sigma_{\mathrm{H}}^{50\%}$	$\sigma\rho_{1\mathrm{H}}^{50\%}$	$\rho_{1\mathrm{H}}^{50\%}$
A) m = 2,3; 5/2009 to 8/2018											
μ	11.22	4.92	8.31	7.16	7.19	6.74	6.01	9.46	9.45	9.21	8.85
SR	0.89	1.92	1.40	2.10	1.56	1.63	1.56	1.65	1.47	1.43	1.39
Std	12.64	2.56	5.94	3.42	4.60	4.13	3.86	5.75	6.41	6.45	6.36
Skw	-0.31	2.65	-0.37	2.31	0.94	1.09	1.20	-0.51	-0.25	-0.15	-0.14
α		5.81	3.15	8.55	7.77	7.11	6.46	4.54	4.14	3.80	3.47
t-α		6.38	6.40	8.13	5.27	5.15	5.03	8.08	5.36	5.22	5.12
β		-0.08	0.46	-0.12	-0.05	-0.03	-0.04	0.44	0.47	0.48	0.48
t-β		-2.74	30.76	-3.88	-1.13	-0.71	-0.95	26.88	20.32	20.79	22.15
B) m = 2; 5/2009 to 8/2018											
μ	11.22	3.70	7.68	4.63	4.71	5.04	4.94	8.17	8.18	8.34	8.29
SR	0.89	1.58	1.24	1.82	0.91	1.07	1.14	1.38	1.16	1.20	1.21
Std	12.64	2.35	6.21	2.54	5.15	4.72	4.33	5.92	7.04	6.95	6.84
Skw	-0.31	1.68	-0.34	2.05	0.76	0.70	0.97	-0.47	-0.28	-0.18	-0.17
α		4.10	2.27	5.54	4.30	4.64	4.64	3.01	2.37	2.54	2.54
t-α		4.67	4.82	7.03	2.46	2.90	3.07	7.21	2.63	3.05	3.22
β		-0.04	0.48	-0.08	0.04	0.04	0.03	0.46	0.52	0.52	0.51
t-β		-1.18	31.00	-3.45	0.57	0.58	0.47	38.55	16.15	16.59	18.02
C) m = 3; 11/2009 to 8/2018											
μ	9.66	7.37	8.81	11.07	11.05	9.65	8.40	10.66	10.71	9.99	9.36
SR	0.78	1.60	1.64	2.02	1.32	1.26	1.13	1.89	1.69	1.62	1.53
Std	12.37	4.62	5.38	5.47	8.35	7.64	7.42	5.64	6.33	6.17	6.12
Skw	-0.36	2.06	-0.64	2.09	-0.31	-0.64	-0.70	-0.62	-0.39	-0.47	-0.39
α		9.22	4.92	12.82	13.00	11.48	10.20	6.73	6.88	6.10	5.46
t-α		6.54	6.52	6.96	5.31	4.78	4.40	6.85	5.50	4.97	4.59
β		-0.19	0.40	-0.18	-0.20	-0.19	-0.19	0.41	0.40	0.40	0.40
t-β		-4.52	18.28	-3.12	-3.97	-3.88	-3.80	13.43	15.08	15.96	15.85

Table 4.10

LETPs as a Diversification Instrument: Equity Emerging

This table reports portfolio performance metrics for LETP and ETP strategies in equity emerging markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. As a diversification argument, a 50%-50% allocation between either unconditional or high LETP portfolios and same asset class ETP market portfolio is built. Namely, these portfolios are 50% invested in one of the LETP portfolios and 50% invested in ETP market portfolio. For instance, $\sigma_H^{50\%}$ is the portfolio that invests 50% is the high tercile sorted by σ and 50% in ETP market portfolio. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	LETP$^{50\%}$	β_{H}	σ_{H}	$\sigma\rho_{1\mathrm{H}}$	$\rho_{1\mathrm{H}}$	$\beta_{\mathrm{H}}^{50\%}$	$\sigma_{\mathrm{H}}^{50\%}$	$\sigma\rho_{1\mathrm{H}}^{50\%}$	$\rho_{1\mathrm{H}}^{50\%}$
A) m = 2,3; 5/2009 to 8/2018											
μ	5.99	7.81	7.45	9.24	9.13	8.61	8.19	8.19	8.14	7.89	7.68
SR	0.32	1.43	0.86	1.36	1.35	1.25	1.18	0.93	0.93	0.91	0.88
Std	18.48	5.47	8.69	6.80	6.76	6.88	6.95	8.83	8.73	8.68	8.70
Skw	-0.02	-0.48	-1.06	-0.32	-0.19	-0.40	-0.42	-1.19	-1.00	-0.89	-0.88
α		8.44	4.75	9.92	9.87	9.40	8.97	5.52	5.50	5.27	5.06
t-α		5.64	6.44	4.77	4.47	4.69	4.47	5.36	5.03	5.23	5.01
β		-0.11	0.45	-0.11	-0.12	-0.13	-0.13	0.45	0.44	0.44	0.44
t-β		-2.20	20.28	-2.00	-2.24	-2.46	-2.46	16.46	17.11	17.66	17.91
B) m = 2; 5/2009 to 8/2018											
μ	5.99	5.02	6.00	4.59	5.28	5.60	5.55	5.81	6.16	6.32	6.30
SR	0.32	1.14	0.67	0.79	0.88	1.11	1.10	0.64	0.67	0.72	0.72
Std	18.48	4.42	8.97	5.83	5.99	5.03	5.03	9.12	9.15	8.81	8.78
Skw	-0.02	-0.45	-0.85	-0.68	-0.66	-0.47	-0.52	-0.78	-0.95	-0.66	-0.67
α		5.39	3.18	4.99	5.68	6.11	6.08	2.99	3.34	3.56	3.55
t-α		4.19	5.02	2.96	3.24	4.03	4.00	3.61	3.90	4.73	4.70
β		-0.06	0.47	-0.07	-0.07	-0.09	-0.09	0.47	0.47	0.46	0.46
t-β		-1.59	27.00	-1.45	-1.40	-2.19	-2.29	22.59	21.58	26.79	26.87
C) m = 3; 1/2010 to 8/2018											
μ	1.85	10.05	6.52	16.45	14.32	10.27	8.74	9.88	8.78	6.69	5.91
SR	0.11	1.40	0.79	1.60	1.45	1.15	1.01	1.22	1.06	0.80	0.71
Std	17.63	7.16	8.21	10.26	9.90	8.96	8.62	8.12	8.28	8.34	8.28
Skw	-0.29	-0.35	-1.72	1.14	0.95	-0.61	-0.70	-1.14	-0.96	-0.95	-0.92
α		10.32	5.73	16.91	14.72	10.60	9.06	9.18	8.05	5.93	5.15
t-α		5.57	6.21	5.65	4.69	3.91	3.65	5.92	5.02	4.32	4.08
β		-0.15	0.43	-0.24	-0.22	-0.18	-0.17	0.37	0.39	0.41	0.41
t-β		-2.12	12.85	-3.40	-2.57	-2.43	-2.48	10.49	9.54	11.89	12.49

4.7 Appendix

4.7.1 Additional Data Procedures

Recording error detection for ETFG dataset. Whenever ETFG data is used, I compute daily returns as $r_{t+1} = \frac{NAV_{t+1}}{NAV_t} - 1$. In which NAV_t is the Net Asset Value at time t. I exclude extreme daily returns that are ten scaled median absolute deviations (MAD) away from the median. I use MAD in place of standard deviation as suggested in Leys et al. (2013). I divide the recording error detection in two parts: either (i) during portfolio construction or (ii) during the return holding period. In the former case (i), I compute MAD with daily return data over the year preceding portfolio construction. In the latter case (ii), I compute MAD with daily return data comprising the month preceding the day of portfolio construction and the month over which the position is held. I choose to use a local distribution in point (ii) because jumps cluster in frequency and size locally (Lahaye et al. (2011) and Lee and Wang (2018)). However, the conceptual conclusions of this paper are robust to the following changes:

- Excluding extreme daily returns that are five, ten or fifteen scaled median absolute deviations (MAD) away from the median.
- Computing MAD by using 1 month, 2 months, 1 year of data preceding or around the holding period return.
- Computing MAD by using full sample data.
- Using only CRSP data. Table 4.7.5 shows high volatility asset classes analysis of Section 4.5.3 using only CRSP data. Table 4.7.6 shows the high volatility asset class analysis using only CRSP data and including 2008 crisis. Despite having less than 75% of the sample, CRSP results confirm the pattern in the data.

In the sensitivity analysis, ρ_1 is the sorting measure that exhibits the least robust selection ability.

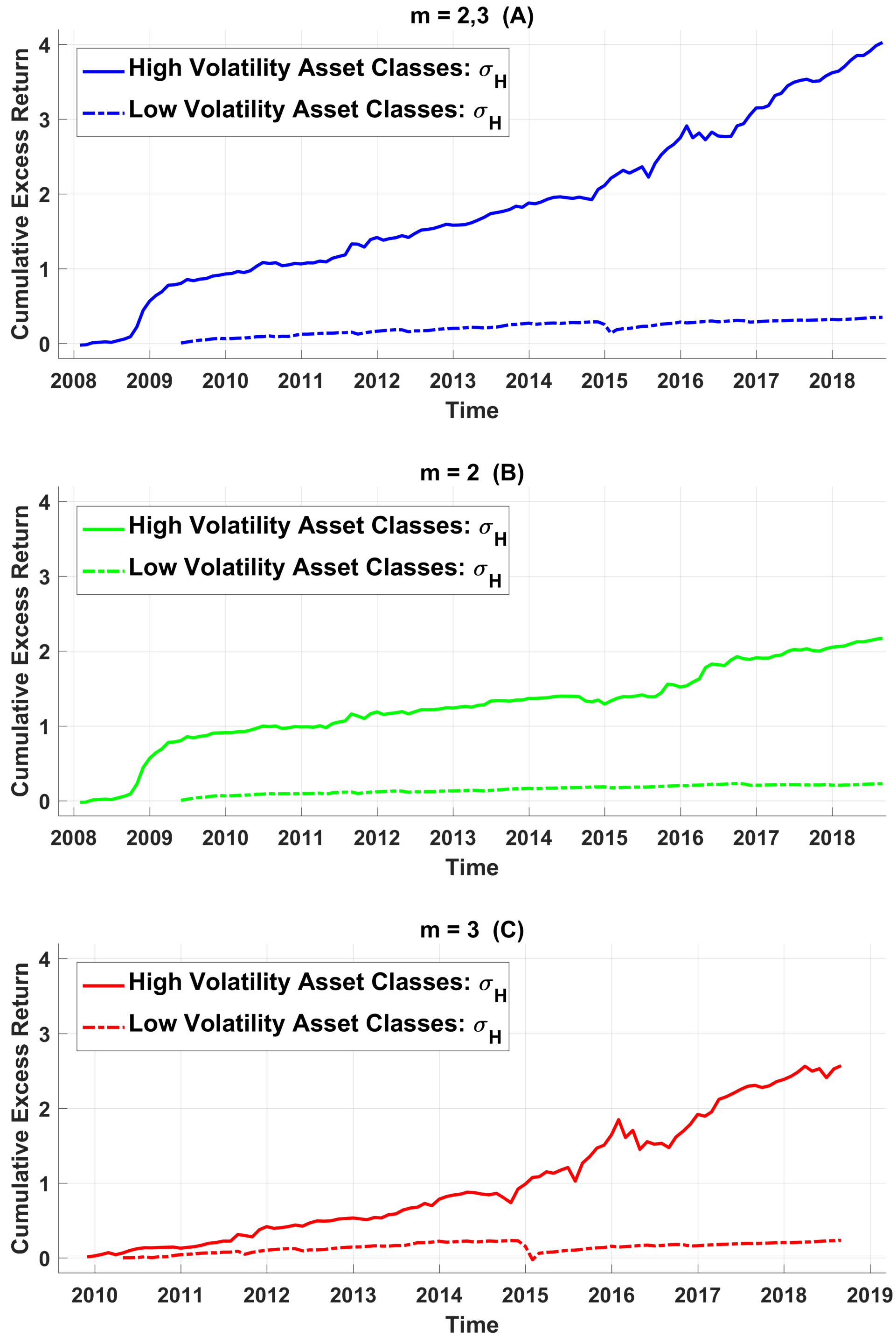

Figure 4.7.1

LETP Slippage in High and Low Volatility Asset Classes, Including 2008

This figure shows cumulative excess returns of high and low volatility asset classes LETP portfolios. High volatility asset classes include equity developed, equity emerging and commodity markets. Low volatility asset classes include fixed income and currency markets. For each high and low volatility asset classes, the figure reports high (H) tercile LETP portfolios sorted by σ (labeled σ_H). See Table 4.7 and 4.8 for additional information on portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel.

Table 4.7.1

Sample Overview: LETP & ETP Instruments.

This table reports the number of LETP and ETP instruments available by asset class over the full sample period. The considered markets are: equity developed, equity emerging, commodity, fixed income and currency. Panel A presents the total number of LETPs pooling together both double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C presents the number of LETPs by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. The sample period is shown in each panel.

	Eq. Developed		**Eq. Emerging**		**Commodity**		**Fixed Income**		**Currency**	
	ETP	LETP	ETP	LETP	ETP	LETP	ETP	LETP	ETP	LETP
A) m = 2,3;	*5/2008 to 8/2018*		*5/2008 to 8/2018*		*12/2008 to 8/2018*		*5/2008 to 8/2018*		*12/2008 to 8/2018*	
	1293	171	185	26	151	41	395	26	38	10
B) m = 2;	*5/2008 to 8/2018*		*5/2008 to 8/2018*		*12/2008 to 8/2018*		*5/2008 to 8/2018*		*12/2008 to 8/2018*	
		108		10		21		12		8
C) m = 3;	*11/2008 to 8/2018*		*1/2009 to 8/2018*		*5/2012 to 8/2018*		*4/2009 to 8/2018*		*5/2012 to 2/2015*	
		63		16		20		14		2

Table 4.7.2

Cross-Section of LETP Slippage Including 2008: Equity Developed

This table reports portfolio performance metrics for LETP and ETP strategies in equity developed markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 1/2008 to 8/2018										
μ	5.43	7.00	10.14	4.96	10.20	4.80	9.11	6.24	7.80	6.58
SR	0.33	1.77	1.87	1.22	1.65	1.61	1.71	1.44	1.68	1.42
Std	16.33	3.96	5.43	4.07	6.19	2.98	5.34	4.35	4.66	4.63
Skw	-1.01	3.02	2.76	0.89	1.92	3.20	2.03	2.78	1.75	2.87
α		7.54	10.88	5.27	10.85	5.31	9.67	6.77	8.28	7.14
t-α		4.97	5.30	3.84	4.54	5.03	4.91	4.38	5.08	3.98
β		-0.10	-0.14	-0.06	-0.12	-0.09	-0.10	-0.10	-0.09	-0.10
t-β		-2.19	-2.50	-1.31	-1.64	-2.99	-1.49	-2.38	-1.83	-2.24
B) m = 2; 1/2008 to 8/2018										
μ	5.43	5.93	7.92	5.13	8.03	4.58	7.61	5.45	6.87	5.76
SR	0.33	1.52	1.55	1.01	1.21	1.61	1.31	1.31	1.36	1.29
Std	16.33	3.90	5.11	5.09	6.64	2.85	5.80	4.16	5.04	4.47
Skw	-1.01	3.01	3.29	0.99	1.65	3.53	1.59	3.25	1.44	3.29
α		6.36	8.56	5.27	8.45	5.03	8.00	5.89	7.17	6.23
t-α		3.85	3.93	3.06	3.03	4.53	3.50	3.63	3.71	3.30
β		-0.08	-0.12	-0.03	-0.08	-0.08	-0.07	-0.08	-0.06	-0.09
t-β		-1.57	-2.03	-0.48	-0.88	-2.43	-0.88	-1.93	-0.94	-1.82
C) m = 3; 11/2009 to 8/2018										
μ	9.66	7.37	11.07	4.53	11.05	4.84	9.65	6.18	8.40	6.33
SR	0.78	1.60	2.02	0.68	1.32	1.29	1.26	1.21	1.13	1.24
Std	12.37	4.62	5.47	6.68	8.35	3.75	7.64	5.09	7.42	5.10
Skw	-0.36	2.06	2.09	-1.51	-0.31	1.45	-0.64	1.24	-0.70	1.23
α		9.22	12.82	6.06	13.00	6.65	11.48	8.13	10.20	8.34
t-α		6.54	6.96	3.01	5.31	5.73	4.78	5.31	4.40	5.90
β		-0.19	-0.18	-0.16	-0.20	-0.19	-0.19	-0.20	-0.19	-0.21
t-β		-4.52	-3.12	-4.34	-3.97	-4.80	-3.88	-3.82	-3.80	-4.01

Table 4.7.3

Cross-Section of LETP Slippage Including 2008: Equity Emerging

This table reports portfolio performance metrics for LETP and ETP strategies in equity emerging markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 11/2008 to 8/2018										
μ	7.19	12.60	13.96	12.00	13.86	11.38	13.37	10.38	12.97	10.67
SR	0.37	1.14	1.20	1.07	1.19	1.03	1.14	0.93	1.10	0.96
Std	19.47	11.03	11.66	11.20	11.65	11.05	11.73	11.13	11.78	11.11
Skw	0.11	5.72	4.71	5.50	4.76	5.87	4.64	5.62	4.59	5.62
α		13.74	15.15	13.10	15.10	12.46	14.66	11.22	14.25	11.54
t-α		2.96	3.15	2.81	3.11	2.64	3.07	2.34	2.98	2.42
β		-0.16	-0.17	-0.15	-0.17	-0.15	-0.18	-0.12	-0.18	-0.12
t-β		-2.28	-2.22	-2.22	-2.36	-2.30	-2.53	-1.63	-2.53	-1.66
B) m = 2; 11/2008 to 8/2018										
μ	7.19	9.96	9.54	10.06	10.20	10.33	10.50	8.35	10.46	9.23
SR	0.37	0.93	0.84	0.94	0.90	0.97	0.96	0.77	0.96	0.85
Std	19.47	10.68	11.31	10.73	11.37	10.64	10.91	10.87	10.91	10.85
Skw	0.11	6.54	5.42	6.47	5.29	6.67	6.07	6.24	6.06	6.21
α		10.82	10.43	11.01	11.09	11.31	11.51	9.04	11.48	9.94
t-α		2.30	2.16	2.34	2.29	2.43	2.43	1.86	2.42	2.06
β		-0.12	-0.12	-0.13	-0.12	-0.14	-0.14	-0.10	-0.14	-0.10
t-β		-1.82	-1.79	-2.10	-1.76	-2.25	-2.17	-1.40	-2.22	-1.42
C) m = 3; 1/2010 to 8/2018										
μ	1.85	10.05	16.45	9.67	14.32	6.46	10.27	10.55	8.74	10.97
SR	0.11	1.40	1.60	1.18	1.45	0.93	1.15	1.29	1.01	1.37
Std	17.63	7.16	10.26	8.20	9.90	6.97	8.96	8.21	8.62	8.00
Skw	-0.29	-0.35	1.14	-0.40	0.95	-0.33	-0.61	0.46	-0.70	0.43
α		10.32	16.91	9.83	14.72	6.67	10.60	10.82	9.06	11.22
t-α		5.57	5.65	4.53	4.69	3.74	3.91	4.88	3.65	4.95
β		-0.15	-0.24	-0.08	-0.22	-0.12	-0.18	-0.15	-0.17	-0.14
t-β		-2.12	-3.40	-0.89	-2.57	-1.76	-2.43	-1.92	-2.48	-1.85

Table 4.7.4

Cross-Section of LETP Slippage Including 2008: High Volatility Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies in high volatility asset classes which includes: equity developed, equity emerging and commodity markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. After this, the top 50% most liquid LETPs are selected in the cross-section. The liquidity measure is defined as the LETP average daily volume over three months preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 1/2008 to 8/2018										
μ	4.01	9.26	13.40	6.54	15.14	5.51	12.25	8.02	10.48	8.94
SR	0.25	1.80	1.78	1.44	1.82	1.55	1.66	1.59	1.61	1.59
Std	16.31	5.14	7.51	4.55	8.34	3.56	7.37	5.04	6.52	5.61
Skw	-1.04	3.08	3.49	0.67	2.71	2.83	2.28	2.29	1.44	2.41
α		9.88	14.13	7.06	15.98	5.98	13.11	8.56	11.22	9.50
t-α		5.45	5.00	5.25	5.19	5.39	5.43	5.04	5.71	4.43
β		-0.15	-0.18	-0.13	-0.21	-0.12	-0.21	-0.13	-0.19	-0.14
t-β		-2.88	-2.96	-3.28	-2.64	-3.20	-3.05	-3.35	-4.16	-2.50
B) m = 2; 1/2008 to 8/2018										
μ	4.01	7.25	9.52	5.99	10.82	4.71	9.81	6.12	8.66	7.07
SR	0.25	1.51	1.36	1.28	1.38	1.47	1.53	1.30	1.62	1.32
Std	16.31	4.79	7.01	4.66	7.86	3.21	6.40	4.71	5.34	5.36
Skw	-1.04	3.81	4.55	2.93	3.73	3.44	3.99	2.91	3.17	2.86
α		7.74	10.14	6.35	11.44	5.10	10.47	6.58	9.16	7.57
t-α		3.86	3.36	3.73	3.32	4.33	3.92	3.61	4.17	3.33
β		-0.12	-0.15	-0.09	-0.15	-0.10	-0.16	-0.12	-0.13	-0.13
t-β		-2.03	-2.25	-1.82	-1.60	-2.46	-1.93	-2.65	-2.13	-2.10
C) m = 3; 11/2009 to 8/2018										
μ	7.83	9.12	12.06	6.56	14.41	4.86	12.58	6.16	10.58	6.92
SR	0.63	1.66	1.76	0.80	1.36	1.18	1.20	1.21	1.06	1.32
Std	12.44	5.49	6.85	8.21	10.57	4.13	10.52	5.09	9.99	5.25
Skw	-0.39	1.43	0.75	-0.55	-0.35	1.97	-0.19	0.26	-0.04	0.13
α		10.58	13.45	8.11	15.57	6.39	14.09	7.46	12.16	8.18
t-α		7.07	7.35	3.39	5.10	5.21	4.62	5.22	4.11	6.09
β		-0.19	-0.18	-0.20	-0.15	-0.19	-0.19	-0.17	-0.20	-0.16
t-β		-3.89	-3.28	-3.95	-2.35	-4.46	-2.80	-3.38	-2.89	-3.08

Table 4.7.5

Cross-Section of LETP Slippage, Using only CRSP Data: High Volatility Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies in high volatility asset classes which includes: equity developed, equity emerging and commodity markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. After this, the top 50% most liquid LETPs are selected in the cross-section. The liquidity measure is defined as the LETP average daily volume over three months preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) $m = 2,3$; 5/2009 to 6/2018										
μ	10.30	6.37	8.93	4.06	10.37	3.43	8.63	5.56	7.64	5.76
SR	0.79	1.89	1.99	0.94	1.77	1.38	1.55	1.64	1.40	1.69
Std	13.09	3.37	4.50	4.33	5.86	2.48	5.57	3.39	5.45	3.40
Skw	-0.28	1.56	1.69	-1.28	-0.12	1.95	-0.06	0.94	-0.03	0.84
α		7.60	10.46	5.02	11.98	4.53	9.97	6.88	9.08	7.02
t-α		8.17	8.24	3.92	6.92	7.08	5.86	8.41	5.46	8.63
β		-0.12	-0.15	-0.09	-0.16	-0.11	-0.13	-0.13	-0.14	-0.12
t-β		-4.12	-4.11	-4.23	-4.37	-5.04	-3.60	-4.20	-4.17	-3.92
B) $m = 2$; 5/2009 to 6/2018										
μ	10.30	3.71	5.09	2.10	5.30	2.33	4.98	2.94	4.54	3.26
SR	0.79	1.69	1.57	1.14	1.52	1.49	1.75	1.20	1.73	1.33
Std	13.09	2.20	3.24	1.85	3.48	1.56	2.84	2.45	2.62	2.46
Skw	-0.28	1.45	1.64	0.85	0.64	0.99	1.10	-0.09	1.24	0.09
α		4.40	5.99	2.64	6.08	2.91	5.69	3.68	5.29	3.88
t-α		6.93	5.92	4.47	5.93	7.07	6.90	5.59	6.94	5.89
β		-0.07	-0.09	-0.05	-0.08	-0.06	-0.07	-0.07	-0.07	-0.06
t-β		-3.19	-3.32	-2.98	-2.65	-4.04	-3.26	-3.06	-3.72	-2.51
C) $m = 3$; 11/2009 to 6/2018										
μ	8.49	8.67	10.09	7.37	13.17	4.67	11.95	6.07	9.99	6.54
SR	0.67	1.58	1.63	0.78	1.23	1.12	1.15	1.17	1.01	1.23
Std	12.77	5.49	6.20	9.43	10.69	4.18	10.36	5.19	9.92	5.33
Skw	-0.36	1.42	0.76	-0.55	-0.51	1.95	-0.15	0.41	-0.11	0.33
α		10.22	11.60	9.16	14.32	6.35	13.37	7.62	11.45	8.10
t-α		6.55	6.68	3.32	4.37	5.09	4.21	5.38	3.56	5.62
β		-0.18	-0.18	-0.21	-0.14	-0.20	-0.17	-0.18	-0.17	-0.18
t-β		-4.00	-3.82	-4.36	-2.40	-4.63	-2.62	-3.88	-2.72	-3.63

Table 4.7.6

Cross-Section of LETP Slippage, Using only CRSP Data and Including 2008: High Volatility Asset Classes

This table reports portfolio performance metrics for LETP and ETP strategies in high volatility asset classes which includes: equity developed, equity emerging and commodity markets. The sample period is shown in each panel. At the beginning of each month, LETPs are paired to corresponding underlying ETPs by maximum absolute correlation. The correlation is computed over the year preceding portfolio construction. After this, the top 50% most liquid LETPs are selected in the cross-section. The liquidity measure is defined as the LETP average daily volume over three months preceding portfolio construction. Then, ETP positions are geared up to the same leverage level as the paired LETP. After that, LETP is sold, while ETP is bought (sold) if the correlation is positive (negative). Then, an unconditional portfolio is built as the equally weighted average of all the LETP-ETP pairs available in the cross-section. This unconditional LETP portfolio is labeled as LETP in the table. Sorted portfolios are built as follows. LETPs and corresponding paired ETPs are sorted in descending order by one of four variability measures (σ, β, ρ_1, $\sigma\rho_1$). Then, they are divided in three groups. Each tercile is equally weighted. The high (H) tercile portfolio is the tercile that should exhibit the largest slippage, vice versa for the low (L) tercile. For example, σ_H is the high tercile sorted by σ. The sorting measures are computed using ETP daily returns over the year preceding portfolio construction. The ranking measures are: realized volatility (σ), CAPM beta of the underlying ETP with respect to the ETP market portfolio (β), first order autocorrelation multiplied by minus one (ρ_1) and the interaction of σ and ρ_1, ($\sigma\rho_1$). In the table, ETP label is the equally weighted ETP market portfolio which comprises all ETP instruments available at portfolio construction. Returns are computed at mid-prices, denominated in US dollars and in excess of US risk-free rate. The panels present different subsamples. Panel A presents results when using LETPs with double and triple absolute leverage multipliers ($m = 2, 3$). Absolute leverage multiplier means that LETPs with both positive and negative leverage exposure are considered. Panels B and C present results by splitting them in double ($m = 2$) and triple ($m = 3$) leveraged instruments, respectively. Each panel presents annualized average return (μ), annualized Sharpe ratios (SR), annualized standard deviations in percentage (Std), skewness (Skw), annualized risk-adjusted return (α), its t-statistic (t-α), ex-post CAPM beta exposure (β), its t-statistic (t-β). Returns and risk-adjusted returns are in percentage. Ex-post CAPM risk-adjusted returns and ex-post beta exposure are with respect to the ETP market portfolio comprising all ETP instruments available at portfolio construction. Newey and West (1987) inference is used to account for heteroskedasticity and autocorrelation.

	ETP	LETP	β_H	β_L	σ_H	σ_L	$\sigma\rho_{1H}$	$\sigma\rho_{1L}$	ρ_{1H}	ρ_{1L}
A) m = 2,3; 1/2008 to 6/2018										
μ	4.54	9.11	13.29	6.04	14.66	5.24	12.13	8.22	10.52	9.07
SR	0.27	1.75	1.75	1.24	1.71	1.49	1.60	1.59	1.50	1.66
Std	16.58	5.20	7.61	4.87	8.57	3.51	7.58	5.16	7.01	5.47
Skw	-1.00	2.98	3.55	-0.14	2.48	2.83	2.17	2.37	2.11	2.42
α		9.82	14.17	6.62	15.64	5.80	13.06	8.92	11.36	9.74
t-α		5.36	4.87	4.54	4.90	5.40	4.97	5.21	5.02	4.71
β		-0.16	-0.19	-0.13	-0.22	-0.12	-0.21	-0.15	-0.18	-0.15
t-β		-3.01	-3.01	-3.24	-2.77	-3.67	-2.76	-3.62	-3.64	-3.06
B) m = 2; 1/2008 to 6/2018										
μ	4.54	6.78	9.94	4.33	10.22	4.28	8.94	5.93	7.82	6.89
SR	0.27	1.43	1.38	1.31	1.35	1.40	1.42	1.24	1.41	1.34
Std	16.58	4.74	7.22	3.31	7.58	3.06	6.29	4.78	5.53	5.14
Skw	-1.00	4.01	4.32	3.11	4.22	3.83	4.51	3.06	5.03	3.08
α		7.39	10.70	4.82	11.05	4.72	9.75	6.51	8.51	7.42
t-α		3.72	3.41	3.74	3.31	3.99	3.72	3.41	3.89	3.26
β		-0.13	-0.17	-0.11	-0.18	-0.10	-0.18	-0.13	-0.15	-0.12
t-β		-2.28	-2.31	-2.43	-2.02	-2.52	-2.16	-2.58	-2.62	-2.13
C) m = 3; 11/2009 to 6/2018										
μ	8.49	8.67	10.09	7.37	13.17	4.67	11.95	6.07	9.99	6.54
SR	0.67	1.58	1.63	0.78	1.23	1.12	1.15	1.17	1.01	1.23
Std	12.77	5.49	6.20	9.43	10.69	4.18	10.36	5.19	9.92	5.33
Skw	-0.36	1.42	0.76	-0.55	-0.51	1.95	-0.15	0.41	-0.11	0.33
α		10.22	11.60	9.16	14.32	6.35	13.37	7.62	11.45	8.10
t-α		6.55	6.68	3.32	4.37	5.09	4.21	5.38	3.56	5.62
β		-0.18	-0.18	-0.21	-0.14	-0.20	-0.17	-0.18	-0.17	-0.18
t-β		-4.00	-3.82	-4.36	-2.40	-4.63	-2.62	-3.88	-2.72	-3.63

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